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Shasta Dam and Reservoir Enlargement
Initial Assessment Study
Central Valley Project, California

Prepared by
Technical Service Center

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BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado

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SHASTA DAM AND RESERVOIR ENLARGEMENT INITIAL ASSESSMENT STUDY CENTRAL VALLEY PROJECT, CALIFORNIA

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I. INTRODUCTION

This technical memorandum documents the results of appraisal-level studies performed by Reclamation's Technical Service Center (TSC) in 1998 for the proposed enlargement of Shasta Dam and Reservoir. These studies were requested by the Mid-Pacific (MP) Regional Office to provide current cost estimates and a cost curve for various dam raise heights, and replace previous studies performed by this office in 1978, 1982, and 1985.

The proposed project is located on the Sacramento River, approximately 12 miles northwest of Redding, California. As the "keystone" of the Central Valley Project, Shasta Dam and Reservoir provide water for irrigation, municipal and industrial use, flood control, hydroelectric power generation, river navigation flows, fish conservation, and recreation. Although not an authorized purpose, Shasta Dam also provides protection of the Sacramento-San Joaquin Delta from ocean salt water intrusion. A Summary Report released in 1988 [1], based on the results of previous studies, concluded it was feasible from an engineering standpoint to enlarge Shasta Dam by up to 213 feet in height, providing additional storage of 9.7 million acre-feet of water and an incremental annual yield of 1.45 million acre-feet. The cost per acre-foot of yield was found to be less than that of 24 alternative water supply projects, based on reconnaissance-level studies. The project was not considered to be either financially or politically feasible however, given the demand for additional water at that time and the extensive investment of public funds required.

Renewed interest in the project has resulted from recent CALFED studies of the San Francisco Bay Delta. The proposed enlargement of Shasta Dam provides tremendous potential for flow management for environmental purposes in the Sacramento River, and has been identified as potentially the least damaging alternative for meeting multiple water resource uses. Other potential CALFED projects include Sites Reservoir (a California Department of Water Resources, or DWR, project), enlargement of Friant Dam (a Reclamation project), the Peripheral Canal (a DWR project), and large-scale fish screen work. The current studies for enlargement of Shasta Dam are being funded under the Central Valley Project Water Augmentation Study.

II. PROJECT DESCRIPTION AND PREVIOUS STUDIES

Shasta Dam is a curved, concrete gravity structure with embankment wing dams on both abutments, designed by Reclamation and constructed between 1938 and 1945. It has a maximum structural height of 602 feet (based on the maximum depth of foundation excavation treatment) and a total crest length of 3,460 feet at elevation 1077.5. The total concrete volume for all features is 6,270,000 yd^3, with an estimated mass concrete volume in the dam of 5,700,000 yd^3. Spillway releases in the central overflow section are controlled by three floating 110- by 28-foot steel drum gates, with 2-foot-high flashboards provided for reservoir storage to elevation 1067. The design discharge capacity for the spillway is 250,000 ft^3/s. Outlet releases are controlled by fourteen 96-inch wheel-type outlet gates and by four 102-inch tube valves, with a combined discharge capacity of 81,800 ft^3/s at elevation 1067. Five steel penstocks deliver water to the powerplant located to the right of the spillway stilling basin, with a current rated capacity of 578 MW. A gated temperature control device (TCD) was recently constructed at the upstream end of the penstocks for selective level withdrawal. Shasta Reservoir has a surface area of 29,740 acres and a total capacity of 4,552,000 acre-feet at the top of joint-use capacity, elevation 1067.

Studies performed for Shasta Dam in 1993 [2], under Reclamation's Safety of Dams (SOD) program, indicated a potential for sudden failure of the spillway drum gates during a large earthquake, due to cracking of the concrete cantilever support walls, failure of the gate hinge anchor bolts, and/or loss of gate buoyancy due to gate or chamber leakage. An uncontrolled release of reservoir storage would result, with downstream releases of up to 205,000 ft^3/s under full reservoir conditions. This was considered to be a dam safety deficiency. Current reservoir evacuation guidelines also cannot be met at Shasta Dam, due to inadequate river outlet release capacity. Under Reclamation policy, any future modifications to the outlet works should include evaluations for increased reservoir evacuation capability [3]. The existing spillway drum gates currently require repairs due to heavy corrosion and deterioration, and the exposed portions of the existing penstocks are subject to rupture due to large earthquake loads [6].

Appraisal designs and estimates for the enlargement of Shasta Dam were first prepared in 1978 for dam crests at elevation 1270 (high) and elevation 1180 (low). The high option included a large embankment section on the left abutment, four reservoir dikes (estimated by the MP Regional Office), and a new spillway with six 55- by 27.5-foot radial gates. Only twelve of the eighteen existing river outlets were to be retained for the high option (to match the existing outlet discharge capacity), requiring the installation of new 102-inch and 126-inch liners, 102-inch ring-follower guard gates, and 96-inch jet-flow regulating gates. The five existing penstocks on the right abutment were to be replaced with five 16-foot-diameter penstocks (with upstream wheel-mounted gates) at elevation 970. Five 20-foot-diameter penstocks (with upstream wheel-mounted gates) were to be provided on the left abutment at elevation 970 to serve a new powerplant. New generating units and switchyards were to be provided for both the existing powerplant and the new powerplant. The low option required a smaller embankment section on the left abutment, one reservoir dike (estimated by the MP Regional Office), and a new spillway with six 52- by 26-foot radial gates. Fourteen of the eighteen existing outlets were to be retained for the low option, with only eight outlets requiring modifications for the higher reservoir head (including new liners, ring-follower gates, and jet-flow gates). The five existing penstocks on the right abutment were to be replaced with five 15-foot-diameter penstocks (with upstream wheel-mounted gates) at elevation 815. Five 20-foot-diameter penstocks (with upstream wheel-mounted gates) were to be provided on the left abutment at elevation 960 to serve a new powerplant. New generating units were to be provided for the new powerplant only, but two new switchyards were to be provided for the low option.

In 1982, the two 1978 appraisal-level cost estimates were updated, and a third option was developed for a dam crest at elevation 1130. The third option included a very small embankment section on the left abutment, no reservoir dikes, and a new spillway with six 55- by 27.5-foot radial gates. River outlet and penstock modifications were assumed the same as for the elevation 1180 option. A new powerplant and two new switchyards were included. The cost estimates for all three options included a 10 percent allowance for unlisted items and a 25 percent allowance for contingencies, but did not include specific allowances for contractor mobilization. The three field costs were used by the MP Regional Office to develop a cost versus dam raise height curve. A Damsite and Structure Review Team Report issued in December 1982 [4] recommended further investigation of the geologic conditions in the left abutment area and a seismotectonic hazard assessment, to establish the technical viability for the proposed enlargement alternatives.

The 1985 appraisal-level studies were based on the 1978 high option designs, but used a dam crest at elevation 1280 (rather than elevation 1270) and included roller-compacted concrete (RCC) gravity wing dams on both abutments as an alternative to the left abutment embankment. The RCC wing dams were to be founded on moderately-weathered bedrock, as determined by additional geologic investigations completed in 1984 [5]. Significant cost savings were indicated with the RCC wing dam alternative, and retention of the existing Upper Vista House and parking lot would be possible. Cellular cofferdam designs were prepared assuming a temporary 100-foot reservoir drawdown, to allow excavation of flat foundation benches on the left abutment and construction of the cofferdam cells in the dry. The effects of earthquake loading on the concrete gravity sections were not considered for the 1985 analysis, but are included in the current studies.

This technical memorandum documents the current studies based on dam crests at elevation 1280 (high), elevation 1180 (intermediate), and elevation 1084 (low), utilizing mass concrete gravity sections with RCC gravity wing dams where required. The current appraisal-level designs for enlargement of Shasta Dam include new spillways, river outlets, reservoir dikes, and hydropower features. A brief discussion of diversion features, potential Pit River Bridge modifications and replacement alternatives, and associated Keswick Dam modifications is also included. Appraisal-level construction cost estimates for all three dam raise options (with a cost curve), and appraisal drawings for the high dam raise option, are included in the Appendix. Finally, design data requirements and potential value engineering alternatives for future studies are discussed.

III. SITE GEOLOGY

Shasta Dam is located in the foothills near the northern end of the Sacramento Valley, in the southern Klamath Mountain Geomorphic Province. Tectonic activity associated with the interactions between the North American, Pacific, and Gorda crustal plates (Mendocino triple junction) where they join about 100 miles west of the dam, has influenced regional geomorphic features. Eruptions at Mt. Shasta, a dormant volcano located about 56 miles northeast of the dam, and at Mt. Lassen, a dormant volcano about 50 miles to the southeast, are attributed to heat developed near the interface between the Gorda and the overriding North American plate. Immense forces generated by the impact and jostling of these plates are believed largely responsible for the faults and the jointed, crushed, and sheared zones that are common to this region, as well as for continuing seismic activity.

The foundation of Shasta Dam consists of the Copley Formation, a sequence of volcanic rocks of Devonian Age (410-360 million years ago), which has been metamorphosed to produce a rock type known as ophiolite, more commonly called greenstone. In the foundation, this rock is fresh and hard where unbroken; however, its integrity has been disturbed by numerous seams consisting of weathered joints, shears, and zones of crushed rock.

All rock on the left abutment is a metavolcanic greenstone of the Copley Formation. Drill hole investigations conducted in 1984 for enlargement of the dam [5] confirmed variably porphyritic to fine-grained meta-andesite flows with occasional medium- to course-grained pyroclastic layers with subordinate brecciated lenses. Weathering effects were found to decrease with depth in all seven drill holes, and the weathering boundaries encountered were generally consistent with the results of a geophysical survey performed in 1982. Eighty-four percent of the rock core recovered was very intensely fractured. Rock strength tests ranged from average to hard rock (unconfined compressive strengths from 5,000 to 16,000 lb/in^2), and permeability was considered low (K from zero to 350 feet per year).

Rock on the right abutment is of similar origin and exhibits similar weathering conditions. Most of the rock recovered in drill holes is moderately to slightly fractured, hard (unconfined compressive strengths from 8,000 to 16,000 lb/in^2), and has a low permeability (K less than 100 feet per year).

Original construction documentation states that the existing dam foundation was explored meticulously and zones of weakness were effectively treated. In general, the quality of the foundation improves with depth and despite enormous numbers of cracks, the individual pieces or blocks are sound and fit together tightly. A formal evaluation of the existing dam foundation for any discontinuities which may result in potential instability has been recommended under the Safety of Dams program (1997-SOD-A); however, no problems are expected to be found.

IV. LOADING CONDITIONS

A. Reservoir Operations During Construction

Mean monthly reservoir elevations for minimum, maximum, and average operating conditions from 1944 to 1997 are summarized in table 1 below. A mean annual reservoir level at elevation 1010 was assumed for the appraisal studies except for construction of the left abutment cofferdam, which will require an additional drawdown to minimum elevation 965 for a period of approximately 5 to 6 months. This additional drawdown would be scheduled for the months of August through February to minimize potential impacts to reservoir operations.

Table 1. - Mean Monthly Shasta Reservoir Elevations, 1944-1997 (feet)

Month	Minimum	Maximum	Average
January	700	1053	998
February	787	1045	1008
March	846	1053	1021
April	884	1063	1036
May	895	1067	1040
June	890	1066	1036
July	866	1060	1023
August	843	1049	1007
September	839	1037	995
October	849	1032	991
November	846	1036	992
December	852	1033	995
Mean Annual	841	1050	1012

B. Design Floods

The current probable maximum flood (PMF) for Shasta Dam has a peak inflow of 623,000 ft^3/s and a 15-day volume of 4,266,000 acre-feet. The PMF was developed in 1984 using probable maximum precipitation (PMP) values from Hydrometeorological Report (HMR) No. 36, and includes a winter season 100-year rain-on-snow flood component. A 1995 screening of PMP values based on the new HMR No. 58 showed a reduction in total precipitation of 8.93 inches over 72 hours, and a reduction of 0.47 inches at 6 hours. Applying the ratio of 6-hour precipitation values (HMR No. 58 to HMR No. 36) to the current peak inflow provides a rough approximation for the new PMF peak inflow of 567,000 ft^3/s, or 91 percent of the current value. The new 15-day volume is estimated to be 3,859,900 acre-feet, or 80 percent of the 1984 PMF volume without the 100-year flood volume [6]. Formal determination of the new PMF will be performed for future feasibility-level studies.

Frequency flood hydrographs were developed in 1985 for the winter season, and are summarized in table 2 below. An updated frequency flood study is recommended for future feasibility-level studies.

Table 2. - Frequency Floods for Shasta Dam

Flood Frequency	Peak Inflow (ft3/s)	15-Day Volume (a-f)
25-year	187,000	1,773,400
50-year	219,000	2,016,900
100-year	251,000	2,235,600

Mean monthly streamflow data for Shasta Dam from 1922 to 1996 were obtained from Water Supply reports, and were averaged to represent normal inflow conditions. These values range from less than 4,000 ft^3/s from July through October, to nearly 14,000 ft^3/s in February and March, as indicated in table 3 below.

Table 3. - Mean Monthly Streamflow Data, Shasta Reservoir

Month	Streamflow (ft3/s)	Month	Streamflow (ft3/s)
January	11,201	July	3,815
February	13,981	August	3,430
March	13,609	September	3,482
April	11,603	October	3,963
May	8,189	November	5,637
June	5,339	December	8,525

C. Earthquakes

An analysis of the local/near regional seismicity and tectonics was performed for Spring Creek Debris Dam in 1994, but applies equally to Shasta Dam. Based on this study, the primary seismic hazard to Shasta Dam is from strong shaking associated with a random earthquake. The maximum credible earthquake (MCE) for this event is a magnitude M_L 6-1/2 with an epicentral distance of 8 km, assuming an annual probability of exceedance of 1 in 50,000. A median peak horizontal acceleration (PHA) of 0.46g was estimated based on an average of five empirical methods for evaluating shallow crustal earthquake sources in the western United States. This PHA is significantly greater than the 0.1g horizontal and vertical accelerations used for the original design of Shasta Dam. The 1978 studies for the enlargement of Shasta Dam assumed a 0.05g horizontal acceleration and a 0.025g vertical acceleration, based on an MCE magnitude M_L 8 with an epicentral distance of 90 miles.

Ground motions used for dynamic analysis of the high dam raise option are described in the structural analysis summary provided in Appendix A.

V. REMOVAL OF EXISTING STRUCTURES

Enlargement of Shasta Dam will require the removal of existing structures on the dam crest, including the parapet walls and crest cantilever, sidewalks, curbing, crane rails, and spillway bridge. The existing elevator towers are assumed to be retained for the low dam raise option only. The spillway drum gates and frames, cantilever support walls, control equipment, and bridge piers must be removed for all dam raise options to accommodate the new spillway gates. The high and intermediate dam raise options require a mass concrete overlay on the downstream face of the existing dam, and will require the complete removal of the spillway training walls, and minor excavation of the stilling basin floor at the downstream toe contact. The existing concrete surfaces will be prepared for new concrete placement by the application of high-pressure water jets (over 6,000 lb/in^2), consistent with normal practice for preparing construction joints, rather than bush-hammering or sand-blasting assumed in previous studies. This method of surface preparation was used successfully for the modifications to Theodore Roosevelt Dam in Arizona.

All cost estimates assume the existing 125-ton gantry crane will be replaced with new equipment, due to its age (over 50 years old). Other mechanical equipment to be removed includes various river outlet gates and valves, steel piping, and operating equipment. All concrete and mechanical equipment to be removed from the dam will become the property of the contractor and will be removed from the site. Waste disposal sites have not been identified for this study, but are assumed to be located within 10 miles from the dam.

VI. CONCRETE DAM RAISE ALTERNATIVES

A. Crest Elevation 1280 (High Option)

The existing concrete gravity dam section between stations 9+40 and 38+00 will be raised 202.5 feet using a mass concrete overlay on the existing dam crest and downstream face. The upstream face within the curved nonoverflow sections will extend vertically to the new dam crest at elevation 1280, and the downstream face will have a 0.7:1 slope from an intersection point (P.I.) at elevation 1280 to the foundation contact at the downstream toe (to lightly weathered rock). The mass concrete will be placed in alternating high-low blocks, with 10-foot lift heights and keyed contraction joints, similar to the recent dam raise modifications to Theodore Roosevelt Dam in Arizona. A mass concrete mix design using 4-inch maximum size aggregate and 370 pounds of cementitious materials per cubic yard (consisting of 70 percent cement and 30 percent pozzolan) was assumed, for a design compressive strength of 4,000 lb/in^2 at 1 year. Cooling coils will be provided on the lift surfaces for circulation of cooling water to limit temperature development of the fresh concrete, and for final cooling for contraction joint grouting. Metal pipe will be provided for pressure grouting the vertical contraction joint faces between the blocks, in 60-foot lifts delineated by 12-inch PVC waterstops (used as grout seals). Due to the thickness of the concrete overlay, a longitudinal contraction joint may be required, which would also be keyed and grouted. Flat drains will be installed on the existing dam face between the contraction joints in every other lift (20-foot vertical spacing) for collection of any seepage. Vertical collector drains (assumed 18-inch-diameter) will be located at the mid-point of each block to carry flat drain seepage to outlets near the toe. The existing 5-inch-diameter vertical formed drains near the upstream face will be extended to the new dam crest, with removable caps for future cleaning. The dam crest will be completed with a crest cantilever for the roadway surface, sidewalks, and parapet walls. The existing elevator shafts will be extended to the new dam crest, and new elevator towers will be provided.

The overflow (or spillway) section will require a thicker section to accommodate the gated spillway crest (similar to the profile for the existing spillway), achieved for this study by raising the P.I. to about elevation 1297, while maintaining the same 0.7:1 downstream slope. Future designs will likely refine this area further, possibly with a steeper slope below the nappe to minimize the concrete volume. A stepped flow surface will also likely be required (see Section VIII). The transverse galleries outside the existing spillway training walls will be extended to the new downstream face, as will the air vent pipe inlets for the river outlet gates. Additional galleries will also be provided within the concrete overlay and crest sections, at locations to be determined.

The left and right abutments will be excavated to the top of moderately weathered rock, to provide foundations for roller-compacted concrete (RCC) wing dams. Assumed excavation depths average 70 feet on the left abutment and 60 feet on the right abutment, with 1:1 cutslopes, for estimating purposes. This excavation will be performed following the construction of the upstream cellular cofferdams (see Section X), and will include the removal of embankment materials and concrete core walls. Blanket grout holes (B-holes) are assumed to be required for the entire RCC foundation surface, spaced on 20-foot centers to depths of 30 feet. Extensive dental concrete treatment may be required for expected shear zones within the excavated foundation surface, and shaping concrete will be required to provide a suitable surface for RCC placement. The RCC will be rolled and compacted in 1- to 2-foot lifts between slip-formed concrete facing elements at the upstream and downstream faces, similar to Upper Stillwater Dam in Utah. This will provide a similar appearance to the mass concrete dam section. The appraisal-level design section is based on a vertical upstream face, a 30-foot crest width, and an 0.8:1 slope for the downstream face. For crest elevation 1280, the left abutment wing dam will extend approximately 1,500 feet between stations 9+40 and -(5+60), and the right abutment wing dam will extend approximately 570 feet between stations 38+00 and 43+70. The end blocks of the mass concrete dam section will be designed to provide a 50- or 60-foot-wide transition between the downstream 0.7:1 and 0.8:1 sloping faces. The RCC mix design is based on a 3-inch maximum size aggregate and a cementitious materials content of 300 lb/yd^3, consisting of 40 percent cement and 60 percent pozzolan. Seepage control measures and contraction joint details for the RCC wing dams will be identified in future feasibility-design studies.

The existing grout and drainage curtains for Shasta Dam will be made deeper for the higher reservoir heads, and will be extended on both abutments beneath the RCC sections. Grout holes (or A-holes) will be spaced on 10-foot centers along the foundation galleries to maximum depths up to 300 feet, or about 40 percent of the reservoir depth. A total of over 490 grout holes will be required, with an average depth of over 225 feet each. Grout takes are expected to average about 3/4 bag per foot of depth. Drain holes will be drilled from the foundation galleries after grouting, to maximum depths up to 200 feet, or about 2/3 the grout hole depths. The existing drain holes are only 50 to 60 feet deep, and are not consistent with current practice. Grouting and drainage tunnels will be provided in each abutment to an estimated 300 feet beyond the RCC contacts, requiring rock bolt and shotcrete tunnel support, and concrete floor slabs.

Extensive instrumentation will be required for the dam raise construction, including thermistors and jointmeters throughout the mass concrete blocks (as used for construction at Theodore Roosevelt Dam), and the existing instruments will be extended or replaced. Specific instrumentation monitoring requirements will be developed in future studies.

The new dam crest will include a crest roadway and spillway bridge, passenger and freight elevators, and three gantry cranes sized to handle mechanical equipment located at the upstream face for the river outlets in the spillway section (60-ton capacity), and for the penstocks for both the existing powerplant (125-ton capacity) and the new powerplant (175-ton capacity). Future studies will evaluate potential refinements of the gantry crane assumptions. A modern lighting system will be provided for the dam crest, and lighting and ventilation will be provided for the new galleries. The proposed configuration of the dam modifications will permit retention of the Upper Vista House and parking lots.

B. Crest Elevation 1180 (Intermediate Option)

The appraisal-level designs for the intermediate dam raise option are very similar to those for the high dam raise option. The existing concrete gravity dam section will be raised 102.5 feet using a mass concrete overlay between stations 9+40 and 38+00, and RCC wing dams will be constructed on both abutments. The left wing dam will extend approximately 1,380 feet between stations 9+40 and -(4+40), and the right wing dam will extend approximately 420 feet between stations 38+00 and 42+20. The mass concrete overlay will extend vertically at the upstream face to elevation 1180, and the downstream face will have a 0.7:1 slope from an intersection point (P.I.) at elevation 1180 to the foundation contact at the downstream toe. The overflow (or spillway) section will be made thicker to accommodate the gated spillway crest by raising the P.I. to about elevation 1197, while maintaining the 0.7:1 slope. The mass concrete overlay for the intermediate dam raise option will be significantly thinner than for the high dam raise option, and may not require a longitudinal contraction joint or an extension of the stilling basin. Grout holes for the intermediate dam raise option will extend to maximum depths up to 260 feet along the foundation galleries, and drain holes will extend to maximum depths up to 160 feet.

C. Crest Elevation 1084 (Low Option)

The low dam raise option requires an increase in dam height of only 6.5 feet, to elevation 1084. The dam raise will be limited to the existing dam crest only, with mass concrete placed in blocks on the existing concrete gravity section, including the new spillway crest section, and with precast concrete panels used to retain compacted earthfill placed on the embankment sections (assuming reinforced-earth methods used for Lake Sherburne Dam in Montana). Construction is assumed to require the removal of selected features from the existing dam crest, including the gantry crane and rails, the spillway bridge, the sidewalks and parapet walls, and miscellaneous concrete on both abutments. The spillway drum gates and control equipment, and the concrete cantilever support walls, would also be removed to accommodate the higher reservoir levels. It is assumed that personnel access can be provided to the existing elevator towers in order to retain them. Although the raised dam crest construction would remain above the new top of joint-use storage, and provide for flood surcharge only, waterstops and other seepage control measures would be provided. The existing 5-inch formed drains in the mass concrete gravity section would be extended to the new dam crest and be equipped with caps for future cleaning. The existing drain holes along the foundation galleries may have to be drilled deeper, but this work was not included in the current cost estimate.

VII. STRUCTURAL ANALYSES FOR DAM RAISE ALTERNATIVES

A. Mass Concrete Gravity Sections

Two-dimensional structural analyses performed for this study indicate a 0.7:1 downstream slope is required for static and dynamic stability of the high dam raise option under the current loading conditions, rather than the 0.6:1 downstream slope previously assumed for the 1985 studies for the same dam crest (elevation 1280). The estimated mass concrete volume corresponding to this proposed section is 5,900,000 yd^3, or 2,270,000 yd^3 (63 percent) greater than the 1985 estimate. This increase is due both to the flatter slope and to an underestimation for the previous mass concrete volume (which was based on a finite element computer model of the existing dam and new concrete overlay), and results in a significant increase in the estimated project cost. A similar configuration is assumed for this study for the intermediate dam raise to crest elevation 1180.

A discussion of the two-dimensional structural analyses performed for the mass concrete gravity section is provided in Appendix A. Future studies should include a three-dimensional analysis to further refine the design sections for any dam raise option considered.

B. Roller-Compacted Concrete Wing Dams

Two-dimensional structural analyses performed for this study confirm the 1985 design configuration for the RCC wing dams. The 0.8:1 downstream slope is considered acceptable for both static and dynamic stability under the current loading conditions. The estimated volume of

RCC in the wing dams is essentially the same as used for the 1985 estimate.

A discussion of the two-dimensional structural analyses performed for the RCC wing dams is provided in Appendix A. Future studies should include a three-dimensional analysis to further refine the design sections for any dam raise option considered. Suitable foundation conditions are assumed to exist on both abutments for the RCC wing dams; however, additional evaluation of the dam foundations should be performed for future studies.

VIII. SPILLWAY AND OUTLET WORKS

A. Structure Layouts

The spillway structure layouts for all three dam raise options are basically the same as used for the previous studies. The existing spillway crest length of 330 feet is retained, but is divided into six 55-foot-long gated sections, rather than the three 110-foot-long openings provided for the existing drum gates. This significantly reduces the spillway bridge spans, and allows a 2:1 gate width to height ratio for design of the new radial gates. A spillway design discharge of 250,000 ft^3/s was selected to match the existing design capacity, and can be provided with a reservoir head of approximately 34 feet on the gated spillway crest. The profile shape for a spillway crest with a vertical upstream face and negligible approach flow velocity can be approximated using compound curves, and requires a thicker section than is assumed for the nonoverflow portions of the raised dam. Location of the radial gates on the crest requires the spillway bridge to be shifted upstream, which affects the horizontal alignment of the crest roadway. The spillway bridge girders should also remain above the water surface for the design flood. The current studies assume the new spillway crest is located 36 feet below the new dam crest, and establishes the top of joint-use storage at the top of the spillway gates. Reservoir capacity data for the three dam raise options, as determined by the spillway design assumptions, are shown in table 4 below. Future studies will further refine the spillway designs to address potential problems with the relative spillway bridge and radial gate locations.

Table 4. - Reservoir Capacity Data for Dam Raise Options

OPTION	DAM CREST ELEVATION	SPILLWAY CREST ELEV.	JOINT-USE AND TOP OF GATES	TOTAL RES. CAPACITY*	INCREASE IN RES. CAPACITY
High	1280.0	1244.0	1271.5	13.89 MAF	9.34 MAF
Intermediate	1180.0	1144.0	1171.5	8.47 MAF	3.92 MAF
Low	1084.0	1048.0	1075.5	4.84 MAF	0.29 MAF
Existing	1077.5	1037.0	1067.0	4.55 MAF	None

* Reservoir capacity estimated from extended data in Appendix C.

Spillway water surface profiles were computed for the high dam raise option to evaluate training wall height requirements, the cavitation potential for the spillway chute, and the energy dissipation requirements of the stilling basin under the higher reservoir heads (see hydraulic analysis summary in Appendix B). This hydraulic analysis confirmed the training wall height assumptions used for the previous studies (30 feet, normal to the slope), but indicated an unacceptably high potential for cavitation damage within the steep spillway chute, and sweepout of the existing stilling basin. Similar conclusions resulted from the dam safety analyses performed in 1993 for operation of the spillway at discharges up to 400,000 ft^3/s during the PMF [2]. The computed cavitation index for spillway releases reaches the 0.2 damage threshold at about elevation 1012, well above the upper tier of river outlet gates, and enters the stilling basin with a maximum flow velocity of about 170 ft/s. Future studies will evaluate the feasibility of a stepped surface for the spillway chute, for air entrainment of the flow and partial energy dissipation before reaching the stilling basin, at least to offset the effects of the higher reservoir head resulting from the dam raise. This would permit the retention of the existing stilling basin and preserve the current energy dissipation capability. The design unit discharge of 667 ft^3/s per foot of width is much larger than is normally considered for stepped spillways, however, and extensive hydraulic model studies would be required for preparation of final designs for the spillway. Other spillway alternatives should be considered for future studies, including a submerged-orifice spillway with top-seal radial gates above the existing dam crest elevation, and the use of air slots or ramps within the spillway chute. The potential for increased flood storage to reduce the spillway design discharge, and the potential addition of an auxiliary spillway at the Jones Valley Dike location, should also be considered.

The existing stilling basin has a 12:1 sloping apron approximately 304 feet long, and walls up to 94 feet high and 392 feet long. Design of a Type V sloping apron basin for the full range of discharges would produce a basin length closer to 500 feet, depending upon tailwater conditions. The high dam raise option will result in a concrete overlay thickness which serves to reduce the existing stilling basin length, and will require at least a corresponding increase in basin length by extending the downstream end of the basin. The existing stilling basin floor and walls were extended 50 feet for the appraisal-level design estimate (high dam raise option only), but further analysis will be required for future studies.

There are three tiers of river outlets in the spillway overflow section - the upper tier has six outlets at elevation 942.0; the middle tier has eight outlets at elevation 842.0; and the lower tier has four outlets at elevation 742.0, for a total of eighteen outlets. All existing river outlets are to be retained for all dam raise options, modified as necessary, to help meet reservoir evacuation requirements. The existing dam does not meet current Reclamation guidelines for emergency evacuation of a high hazard dam, and every reasonable effort should be taken to improve upon the existing evacuation capability. Previous studies limited the river outlet discharge capacity to current levels (about 80,000 ft^3/s), resulting in the proposed plugging of up to six existing outlets. Subsequent cost studies prepared in 1996 indicated the river outlet capacity should be increased to 190,000 ft^3/s to satisfy the California Department of Water Resources (DWR), Division of Safety of Dams emergency release requirements. The reservoir evacuation capability of the proposed dam raise options is addressed in part C below.

B. Mechanical Features

1. Spillway gates. - The existing spillway drum gates will be removed for all dam raise options, due to a seismic loading deficiency, and inability to take higher reservoir loads. Previous studies have shown the drum gates and cantilever support walls to be susceptible to failure during the MCE, and gate stresses may be near maximum allowable values for the current storage level at elevation 1067 (with flashboard gates in place). The drum gates and gate drainage systems are also currently in poor condition, due to extensive corrosion and deterioration of the 50-year-old equipment [7].

The current appraisal-level designs assume the installation of six 55- by 27.5-foot steel radial gates, with a total crest length of 330 feet, as for the previous studies. Radial gates were selected for their economy and operating reliability. Each radial gate would be operated using a gate hoist (with wire ropes) located on an operating deck above the gate. Reservoir storage would be permitted to the tops of the radial gates, which establishes the top of joint-use storage.

The spillway bridge must be located upstream of the radial gates and operating decks to permit their operation, which results in an horizontal offset from the dam crest roadway centerline. Future studies will further refine the spillway crest design to minimize this offset.

2. River outlet gates. - The current studies assume river outlet modifications will include the installation of two 102-inch-diameter ring-follower gates in tandem at the present locations of the 96-inch outlet gates (at elevations 942 and 842) and the 102-inch tube valves (at elevation 742). Ring-follower gates should be more economical than other gate options, and will allow the maximum release capacity for the system, but they are not regulating gates. The upstream gates will serve as guard gates for emergency closure. The downstream gates are only to be operated fully open or fully closed, as is the case for the existing outlet gates. If additional flow regulation is determined to be required, as is now available with the four tube valves, two or more river outlets could be fitted with 96-inch jet-flow gates for a range of gate openings (proposed in previous studies for all river outlets). Larger (126-inch-diameter) linings would be required downstream of the jet-flow gates, however, as required by the previous dam raise studies.

The high dam raise option (crest elevation 1280) will require the replacement of all fourteen outlet gates and all four tube valves, due to the higher reservoir heads. The intermediate dam raise option (crest elevation 1180) will allow the retention of the upper tier of outlet gates, as they were originally designed for the same (higher) head as the middle tier of outlet gates, and could accommodate the 100-foot higher reservoir head. The low dam raise option assumes the replacement of the four existing tube valves, to provide greater operating reliability and improved discharge capacity. The existing tube valves currently experience severe vibration under certain operating conditions, and have operating restrictions outlined in the current Standing Operating Procedures (SOP) [8].

The proposed ring-follower gate size matches the diameter of the existing steel liners (to be retained), and essentially provides a pressure pipe system with downstream control. This configuration was originally specified for Shasta Dam, according to design drawings from 1938. Concrete excavation will be required in both the floor and the roof of the existing gate chambers to permit removal of the existing embedded gates and valves, and installation of the larger ring-follower gates. The new gates would be delivered in sections through the existing elevator shafts and access galleries, for assembly in their final locations. The gate chambers would be completed with concrete backfill, and new gate control systems would be installed.

The installation of tandem gates to meet emergency closure requirements will permit the provision of a more economical, upstream coaster-type bulkhead gate with lifting frame for gate maintenance purposes. Bulkhead gate guides for each river outlet will extend to just below the spillway crest, for installation of the single bulkhead gate using a new 60-ton gantry crane on the spillway bridge. The upstream bulkhead gate will also be used during construction for installation of the new ring-follower gates below the reservoir level.

3. Steel piping for river outlets. - Available drawings show that the river outlets are lined with 102-inch-diameter by 5/8-inch-wall steel pipes equipped with 6- by 3/4-inch stiffener rings welded to the outside surface of the pipes. The stiffener rings are located at 75-inch centers along the entire length of the pipe. The downstream end of each pipe curves downward at an angle of 41°19', where it reduces to a 93-inch-diameter by 5/8-inch-wall steel pipe. The steel for the existing outlets is assumed to be ASTM A89 Grade B (Sy = 24,000 psi and St = 55,000 psi).

The existing 102-inch-diameter steel pipes, as originally designed and shown on the available drawings, are considered to be adequate for the increased external and internal pressures resulting from all dam raise options. The existing pipes would have to be physically and ultrasonically examined to determine whether any pipe wall loss has occurred over the years. For this study, it is assumed that the existing pipes have not experienced any significant pipe wall loss.

The downstream portion of the steel pipe for each river outlet would have to be removed where it begins to bend downward to the 93-inch-diameter end (a length of about 41 feet). Straight sections of new 102-inch piping (with about a 3/4-inch wall thickness) would be added to the existing piping to extend the river outlets to the new downstream face of the dam. The ends of the new outlet pipe extensions would be made similar to the existing ones, with a 41°19' downward angle and a transition to the 93-inch-diameter by 5/8-inch-wall steel pipe.

New 36-inch-diameter steel piping would be connected to the existing air vent pipes located downstream of the ring-follower gates, to provide air to the new gates. The existing air inlet pipes would be extended downstream through the concrete overlay to the new dam face, outside the spillway training walls at approximately elevation 988. New air valves and filling lines would be provided for each gate tandem to fill the space between the two gates.

C. Release Capacities

The spillway design discharge capacity is 250,000 ft^3/s, the same as for the existing spillway. This will permit the retention of the existing stilling basin, and is consistent with the design release capacity of Keswick Dam downstream. A reservoir head (H) of approximately 34 feet above the spillway crest is required to produce the design discharge (Q), which establishes the maximum water surface elevation for each dam option. This head requirement was determined using the weir equation, $Q = CLH^{3/2}$, with an effective crest length of 320 feet (including pier and abutment effects), and a design discharge coefficient (C) of 3.95 (based on an optimum design profile for the overflow crest). Reservoir operating restrictions will be required for flood control, similar to the current requirements provided in the SOP, to limit the initial reservoir level at the beginning of the PMF to that level which results in the desired maximum water surface elevation during passage of the PMF. This level will be somewhere below the top of joint-use storage, and will be dependent upon snowpack conditions within the upstream basin and the time of year. No flood routings were performed for the appraisal-level studies.

Discharge capacities for the modified river outlets were computed based on the existing bellmouth entrance conditions and assumed friction losses through the extended length of each outlet, with trashrack and gate losses assumed to be negligible. Each modified outlet discharge equation has the form, $Q = CH^{1/2}$, with the discharge coefficients (C) dependent upon the length of the outlet. A Mannings' roughness coefficient of 0.012 was used for friction losses within the 102-inch-diameter steel liners. Reservoir head (H) is measured from the centerline of each outlet, at elevations 942, 842, or 742. The resulting maximum discharge capacities for the modified river outlets (high dam raise option) exceed the maximum capacities of the existing outlets at reservoir elevation 1067 by 19 and 15 percent for the upper and middle tier outlets, respectively (due to the smaller size of the existing 96-inch outlet gates), and by 12 percent for the lower tier outlets (due to the reduced discharge efficiency of the 102-inch tube valves). Discharge capacities for the existing river outlets are provided by discharge curves included in the SOP. The maximum combined discharge capacity of all eighteen river outlets is 133,600 ft^3/s at reservoir elevation 1271.5 for the high dam raise option (with all outlets modified), 113,600 ft^3/s at reservoir elevation 1171.5 for the intermediate dam raise option (with twelve outlets modified), and 88,000 ft^3/s at reservoir elevation 1075.5 for the low dam raise option (with four outlets modified).

A reservoir evacuation study was performed for both the high and intermediate dam raise options, with reservoir inflow from the mean monthly streamflow data in table 3 (three highest consecutive months), reservoir storage capacity from tables provided in the SOP and in Appendix C, and reservoir outflow based on the discharge capacities of the new spillway, river outlets, and powerplants. Combined spillway and river outlet discharges were limited to 250,000 ft^3/s so as not to exceed the capacity of the existing stilling basin, and powerplant releases assumed one unit in each powerplant was unavailable (leaving a release capacity of 80 percent). Total releases for emergency evacuation will exceed the safe downstream channel capacity of 79,000 ft^3/s. Hydraulic heights were measured from elevation 576 (with zero reservoir storage - the reported original streambed elevation 544.5 is believed incorrect) to the top of joint-use capacity in each case, and the 10 percent reservoir storage level was based on total storage. With these assumptions, and with the reservoir initially full to the top of joint-use capacity, both dam raise options will meet current Reclamation guidelines for reservoir evacuation, in accordance with ACER Technical Memorandum No. 3 [3] for a high-hazard, low-risk dam, as shown in table 5 below. (Note that the drawdown guidelines to 25 percent of the hydraulic height only apply when physically possible, which is not the case here due to the location of the lowest river outlet and a discharge capacity less than reservoir inflow.)

Table 5. - Reservoir Evacuation Capability of Dam Raise Options

Evacuation Stage	Guidelines (days)	Crest El. 1180 (days)	Crest El. 1280 (days)
75% Hyd. height	30-40	22 (El. 1023)	31 (El. 1098)
50% Hyd. height	50-60	39 (El. 874)	55 (El. 924)
10% Res. storage	60-70	40 (El. 870)	56 (El. 917)
25% Hyd. height	80-100	N/A (El. 725)	N/A (El. 750)

IX. HYDROPOWER FEATURES

A. Selective-Level Withdrawal Intakes

1. Modifications to existing temperature control device. - The five 15-foot-diameter power penstocks that serve the existing powerplant have an intake centerline at elevation 815. Construction of a temperature control device (TCD) to provide selective-level withdrawal capability to the existing penstock intakes was completed in 1997. The temperature control device is a steel structure consisting of a shutter structure and low-level intake structure. High level withdrawal, at or above the existing intake elevation, is controlled by the 250-foot-wide by 300-foot-high shutter structure that encloses all five existing power penstock intakes. Three openings with hoist-operated gates and trashracks on the front of each shutter unit allow selection of the reservoir withdrawal level. The 125-foot-wide by 170-foot-high low-level intake structure, located to the left of the shutter structure, acts as a conduit extension to access the deeper, colder water near the center of the dam. The TCD is designed for a discharge capacity of 19,500 ft^3/s, and has a reservoir operating range between elevations 840 and 1065.

No modifications to the operation of the existing powerplant have been adopted for the current studies. As such, only modifications to raise the TCD operating equipment above the new maximum reservoir water surface elevations have been included in the cost estimates. These modifications include removing the existing hoists, electrical equipment, miscellaneous metalwork, and hoist platform steel from their current locations at elevation 1071.9, and installing new hoists, electrical equipment, miscellaneous metalwork, and hoist platform steel at the new dam crest elevations. The existing rigid frames will remain in place to support the shutters and low level intakes. Sloping trashracks will be added to the top of the shutters at elevation 1067.5 to prevent debris from entering the TCD. The existing temperature monitoring equipment will be extended if possible, or completely raised, to the new hoist platform elevation. New rigid frames will be anchored to the raised dam near the crest elevation to support the new hoists, electrical equipment, miscellaneous metalwork, and hoist platform steel.

2. Modifications to existing penstock intakes. - The centerline of the penstock intakes will remain at elevation 815 and the existing trashrack structures will remain in place. The gate hoist structures above the existing trashrack structures will be removed to elevation 1068.75 and the existing coaster gate operators will be removed. To seal the interior of the dam against the higher reservoir elevations, the stairway between the gate hoist structures and the gallery at elevation 1065 will be plugged with concrete. The reinforced concrete gate hoist structures will then be extended to the new dam crest elevations.

New hoist-operated, 16- by 25-foot wheel-mounted gates (designed for the higher reservoir head) will replace the existing coaster gates for the high and intermediate dam raise options. The existing gate frames around the penstock intakes will be replaced with new gate frames, and the gate guides will be extended to the new dam crest elevations. One set of stoplogs designed for the higher reservoir elevations will be provided. Estimates include quantities for extending the existing stoplog guides to the new dam crest elevations, but do not include items for replacing the existing stoplog guides. It is assumed that the stoplogs will be used to unwater the gated intake area for installing the new gate frames.

3. Selective-level withdrawal for new penstock intakes. - Five new 20-foot-diameter power penstocks through the dam will supply water to a new powerplant on the left abutment for the high and intermediate dam raise options. The total design discharge capacity of the new powerplant will be 30,000 ft^3/s. For the high dam raise, the centerline of the penstock intakes will be located at elevation 970, and the new powerplant will operate for reservoir water surface levels between elevations 995 and 1280, assuming a 25-foot minimum intake submergence requirement. For the intermediate dam raise, the centerline of the penstock intakes will be located at elevation 880, and the new powerplant will operate for reservoir water surface levels between elevations 905 and 1180, again assuming a 25-foot minimum intake submergence requirement. Hoist-operated, 20- by 31-foot wheel-mounted gates and associated gate frames and guides will be installed at each intake. Each intake will have stoplog guides, but only one set of stoplogs will be provided for use on all five new intakes.

The layout of the new penstock intake structures assumes that the reservoir water surface during construction will be at elevation 1010. Above elevation 1010, the intake structures will be reinforced concrete. Below El. 1010, only that part of the intake structure associated with the wheel-mounted gate guides and frames, and stoplog guides and support, will be reinforced concrete; the rest of the intake will consist of steel cladding attached to structural steel frames. Because the penstock intakes will be underwater during construction, it will be necessary to construct the concrete portions of the new intakes to El. 1010 and install the stoplogs, before excavating through the dam for the new penstocks.

Each penstock intake structure will have two openings, with hoist-operated gates and trashracks in front of each opening, to allow selection of the reservoir withdrawal level. For the high dam raise, the five upper gates will act as vertically adjustable intakes (or weirs) between elevations 1125 and 1225. Assuming 35 feet minimum submergence, the upper gates may be operated for reservoir water surface elevations between 1160 and 1280. The five lower gates will control the flow through intakes between elevations 890 and 990. Assuming 25 feet minimum submergence for the penstock intakes, the lower gates may be operated for reservoir water surface elevations between 995 and 1280. To keep entrance velocities around 2 ft/s, the lower gate should be open a minimum of 65 feet.

For the intermediate dam raise, the five upper gates will act as vertically adjustable intakes (or weirs) between elevations 1040 and 1140. Assuming 35 feet minimum submergence, the upper gates may be operated for reservoir water surface elevations between 1075 and 1180. The five lower gates will control the flow through intakes between elevations 830 and 930. Assuming 25 feet minimum submergence for the penstock intakes, the lower gates may be operated for reservoir water surface elevations between 905 and 1180. Again, to keep entrance velocities around 2 ft/s, the minimum lower gate opening should be 65 feet.

B. Penstocks

1. Existing penstocks. - Embedded portions of the five existing 15-foot-diameter steel penstocks must be replaced with new, thicker pipes (with about a 1-1/4-inch wall thickness) for both the high and intermediate dam raise options, to accommodate the potential increase in external hydrostatic pressures when the penstocks are unwatered. This will require concrete excavation within the dam to provide an oversized (approximately 17-foot-diameter) opening for installation and concrete encasement of the new penstocks. Construction will be performed with the upstream wheel-mounted gates and stoplogs in place. The intake centerline will remain at elevation 815, and the design discharge will remain at 19,500 ft^3/s.

Exposed portions of the five existing penstocks between the dam and the powerplant are believed to be adequate for the increase in internal pressure, based on their design thickness and strength ($Sy = 24{,}000$ lb/in^2 and $St = 55{,}000$ lb/in^2 for ASTM A89 Grade B steel). By limiting operation of the existing powerplant units to reservoir levels at or below elevation 1065, the penstocks will be subjected to higher static heads only, without potential waterhammer loads. The ring girder supports for the exposed penstocks will have to be strengthened for maximum potential earthquake loads, however, and additional concrete saddle supports must be provided. This will correct a design deficiency of the existing penstock installation for all dam raise options.

The existing spiral cases within the powerplant are not adequate for the increase in static internal pressure under the high dam raise option (for reservoir levels above approximately elevation 1186, or 600 feet of reservoir head). A 15-foot-diameter butterfly isolation valve will be provided for each penstock to isolate the powerplant from higher reservoir heads, as a precaution. Filling lines and air valves are provided for the isolation valves. The current design studies assume the isolation valves are located in five new valve vaults immediately upstream of the powerplant; however, the valves could be located at the downstream toe of the dam, where the new embedded penstocks will join the existing exposed penstocks, to reduce the design head for the valves and simplify installation. Mobile crane access should be provided at the valve vaults, since no special valve handling gantry is planned.

2. New penstocks. - Five new 20-foot-diameter steel penstocks (with about a 1-3/4-inch wall thickness) will be provided through the dam on the left abutment, for both the high and intermediate dam raise options, to serve the new powerplant. The centerline of the new penstock intakes will be at elevation 970 for the high dam raise and at elevation 880 for the intermediate dam raise, requiring concrete excavation of an oversized opening (approximately 22-foot-diameter) for each penstock, under reservoir head. This will require construction of the intake structure and installation of the wheel-mounted gates and stoplogs. The exposed portions of the new penstocks between the dam and the new powerplant will be designed for maximum earthquake loads. The assumed design discharge for the new penstocks is 30,000 ft^3/s.

C. Powerplants

1. Existing powerplant. - No modifications are currently planned for the existing powerplant structure for any of the dam raise options, so power generation will be restricted to current reservoir operating levels between elevations 840 and 1065 (with a minimum operating head of 275 feet). The powerplant units are currently rated at 578 MW, but an uprating (generator rewind) program is expected to increase this capacity to 676 MW, with a total plant flow of 19,500 ft^3/s. Upstream isolation valves will be provided for each unit for the high dam raise option. These valves are required to protect the existing spiral cases and will be closed when the reservoir level exceeds an elevation of approximately 1186 feet.

Previous studies included the installation of new turbine/generator units within the existing powerplant, but indicated a potential requirement for major modifications to the existing structure to accommodate the new units and overhead cranes, which were never quantified. Very elaborate and expensive modifications may also be required for the recently constructed TCD to accommodate a higher design discharge. The current studies assume the potential costs to modify the powerplant and TCD would outweigh the benefits, especially with consideration of the uprated capacity of the plant. This assumption should be confirmed for future studies.

2. New powerplant. - A new powerplant structure will be constructed to the left of the spillway stilling basin, for both the high and intermediate dam raise options. The arrangement of the existing powerplant and the new powerplant is assumed to be approximately symmetrical about

the spillway centerline. The current appraisal-level designs include five unit bays, a service bay, and a control bay similar to those found in the existing powerplant. The unit bays for the new powerplant will be 20 feet deeper than for the existing powerplant due to the higher reservoir head, and about 60 feet wide in the longitudinal direction. The concrete quantities for the new powerplant substructure, intermediate structure, superstructure, and second stage construction are all based on a 15 percent increase over the corresponding quantities for the existing powerplant, based on the original construction bid schedule (Specifications No. 780).

The new powerplant will contain five 260 MW turbine/generator units with a design head of 575 feet for the high dam raise option, for a combined plant capacity of 1,300 MW, and will operate between reservoir elevations 980 and 1280 (with a minimum operating head of 402 feet). For the intermediate dam raise option, the new powerplant will contain five 215 MW units with a design head of 482 feet, for a combined plant capacity of 1,075 MW, and will operate between reservoir elevations 890 and 1180 (with a minimum operating head of 313 feet). Total design flow through the new powerplant for both options will be 30,000 ft^3/s, or 6,000 ft^3/s per unit. Two 500-ton overhead travelling cranes will be provided in the new powerplant for both dam raise options.

A service yard will be located at the left end of the new powerplant, with an access road extending alongside the tailrace area downstream to the existing Sacramento River bridge. Approximately 1,500,000 yd^3 of rock excavation will be required for the powerplant, service yard, tailrace, and access road. The existing steep rock wall along the left bank of the river downstream of the spillway may be partially retained to serve as a cofferdam during initial excavation for the plant structure. The new powerplant excavation will require the relocation of the existing switchyard.

D. Electrical Equipment

1. Main generating units. - Five new generators, each rated 260 MW, 0.95 pf at 13,800 volts for the high dam raise option, and 215 MW, 0.95 pf at 13,800 volts for the intermediate dam raise option, will be required for the new powerplant. These generators are of the vertical-shaft synchronous type, and will be provided with a static excitation system.

2. Bus and power circuit breakers. - One 15-kV isolated-phase bus, rated 12,500 amps for the high dam raise option and 11,000 amps for the intermediate dam raise option, will run from each generator through its associated unit power circuit breaker out to the unit transformer. Preliminary single-line drawings for both the high and intermediate dam raise options are provided on figures 1 and 2, to show the proposed power distributions for the new powerplants.

3. Generator step-up transformer. - Three single-phase outdoor transformers will be provided for each unit to transform the generator's 13.8 kV output voltage to 230 kV for use in the new switchyard. One spare transformer will also be provided to minimize down-time for a single transformer failure.

1/30/98

NEW SWITCHYARD AT SHASTA POWERPLANT
Alternative A2
Elevation 1280

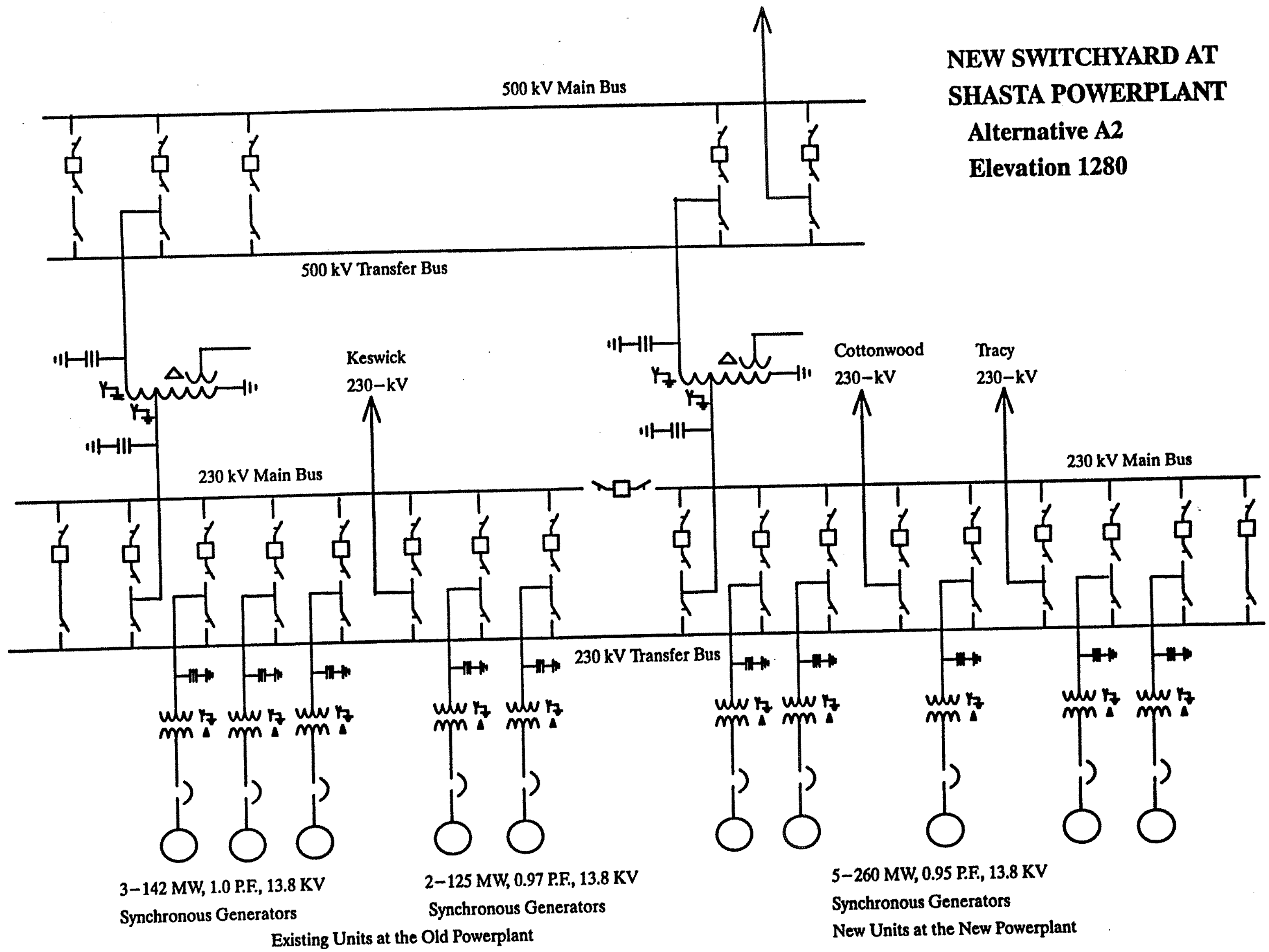

FIGURE 1

NEW SWITCHYARD AT SHASTA POWERPLANT
Alternative B
Elevation 1180

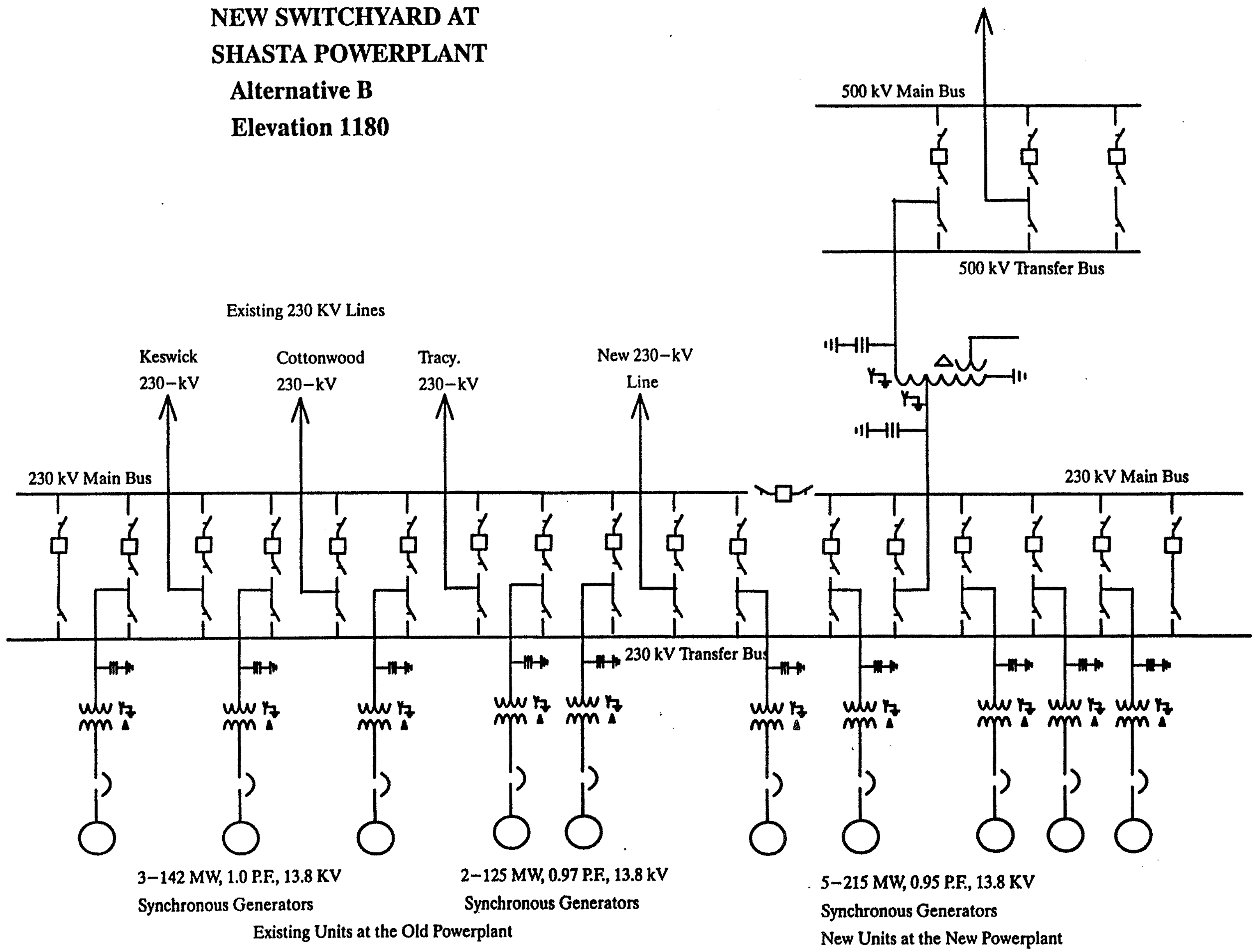

FIGURE 2

4. Station service. - The station service power supply will be obtained by tapping off two of the generators' 13.8 kV-bus, and by providing step-down transformers to transform the voltage down to 480 volts. The plant station service needs will be provided by the 480-volt distribution equipment located inside the plant's double-ended unit substation.

5. Duplex control switchboards. - Duplex control switchboards will provide all control, protective, and monitoring (indication) features required for the main generators. Manual, automatic, and supervisory type functions will be provided to allow full flexibility in plant operations.

6. 600-Volt motor control centers. - 600-volt motor control centers will be provided in the plant for operating all of the auxiliary systems, such as hydraulic pumps, water cooling pumps, electrically driven valves, air compressors, and sump pumps.

E. Switchyards

Prior to commencing construction for the new powerplant, the existing switchyard will be replaced with a new 230 kV switchyard at a downstream location (to be determined), to permit continued power generation to some degree throughout construction using the existing powerplant and available units. A new 525 kV switchyard will be constructed concurrent with construction for the new powerplant, to serve the new plant. Overall site dimensions for the new switchyards were developed for the 1978 studies, as follows: 1,250- by 400-feet for the 230 kV switchyard, 700- by 500-feet for the 525 kV switchyard for dam crest elevation 1270, and 350- by 500-feet for the 525 kV switchyard for dam crest elevation 1180.

Construction of a new 525 kV (and other) transmission lines will be required to accommodate the new power output from both powerplants, but is not included in the current appraisal-level studies.

X. DIVERSION FEATURES

Construction of the new gravity wing dams on both abutments will require the construction of upstream cellular cofferdams. The left abutment cofferdam will consist of four large cloverleaf cells founded on an excavated bench at elevation 970, and three to four smaller circular cells founded on an excavated bench at elevation 1020. The right abutment cofferdam will consist of four small circular cells and connecting arcs above elevation 1050. The cells will consist of interlocking steel sheet piling backfilled with a free-draining sand and gravel material, extending to the existing dam crest at elevation 1077.5. Cell diameters are assumed to be equal to the cell heights to ensure stability. Concrete will be placed to provide water barriers at the contacts with the existing dam and abutments. Excavation of the lower bench and construction of the lower portions of the cloverleaf cells on the left abutment, including the placement of backfill and anchor concrete, will require a reservoir drawdown below average annual operating conditions (minimum elevation 965) for approximately 5 to 6 months. An average drawdown level at elevation 1010 has been assumed for construction of all other diversion features. The steel sheet piling and free-draining backfill will be removed from both locations following construction; however, the backfill and anchor concrete will remain.

Construction of the lower portions of the cellular cofferdams underwater is possible, and has been performed previously on smaller cofferdams in water depths up to about 60 feet. Foundation excavation would be much slower, however, and tremie methods would be required for concrete placement. Construction costs and durations would increase significantly. Further study of potential reservoir operations during construction, and their impacts on construction activities, should be performed for feasibility design.

Diversion and care of streamflow during construction will require a construction sequence to permit continued operation of four of the five existing powerplant units during modifications to the existing penstocks and temperature control device, for power generation and downstream releases. The powerplant release capacity should be sufficient for passage of normal reservoir inflows during construction. Sufficient river outlet capacity must also be maintained throughout construction to provide for passage of potential diversion floods, up to the downstream channel capacity of 79,000 ft^3/s. The current studies assume no more than two river outlets would be unavailable for releases at any time, using the new bulkhead gate and the existing coaster gate to provide upstream closure for gate replacement. Replacement of the four tube valves at elevation 742 should be completed first, to provide increased release capacity from the lower tier of river outlets. Flood releases from river outlets located above the concrete overlay block construction should of course be avoided, but may be required during construction.

Downstream cofferdams will be required within the tailrace area for unwatering the stilling basin and for construction of the new powerplant, to retain tailwater levels during reservoir releases. The stilling basin cofferdam may be subject to overtopping for passage of flood flows from the river outlets. Details for these cofferdams will be developed for future feasibility-level designs.

XI. RESERVOIR DIKES

Four reservoir dikes are required to contain new reservoir levels up to elevation 1280, at the Centimudi, Bridge Bay, Jones Valley, and Clickapudi Creek sites. Reservoir dikes at the Jones Valley and Clickapudi Creek sites only will be required to contain reservoir levels up to elevation 1180. Approximate locations of the reservoir dikes are shown on figure 3. Topographic maps with a scale of 1 inch equals 1000 feet, and with a contour interval of 40 feet, were used to define the characteristics and number of reservoir dikes required to store water at specific maximum levels, and to determine the appraisal-level quantities for each dike. No reservoir dikes are assumed to be required for the low dam raise option, although the available topography suggests some minor protection may be required. Better site topography should be developed for future feasibility-level designs.

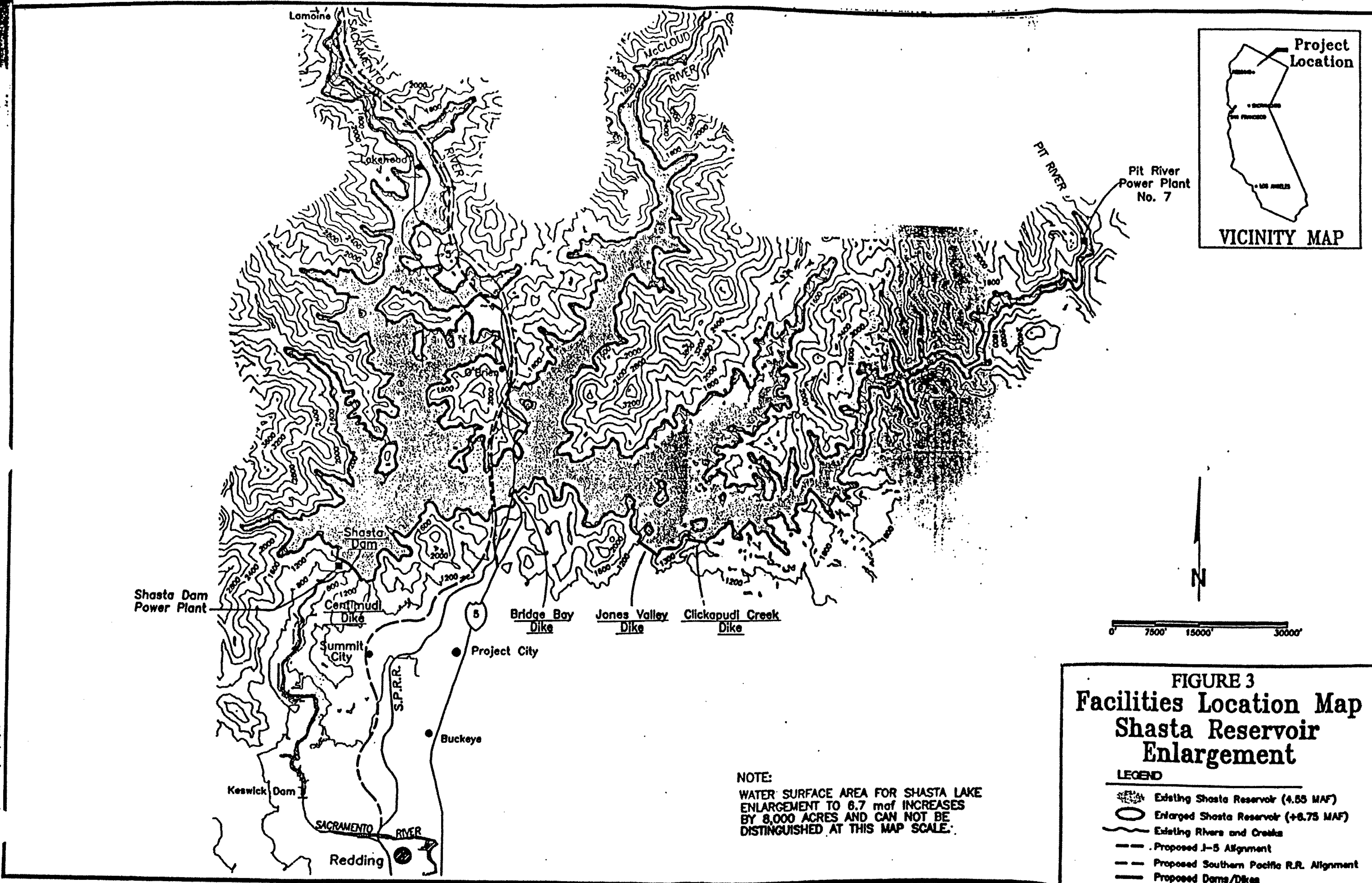

FIGURE 3
Facilities Location Map
Shasta Reservoir Enlargement

The appraisal-level design for each reservoir dike is based on a zoned earthfill structure with a ten foot freeboard allowance. A typical cross section was established for each dike regardless of its structural height. Characteristics of the reservoir dikes are summarized in table 6 below. A cross-section and profile for the Jones Valley Dike (crest elevation 1290.0) is shown on drawing 214-D-23982.

The entire foundation for each dike will be stripped to a suitable depth, with special attention to the contact surface for the central impervious core. A core trench will be excavated to reduce the potential seepage through the foundation. The depth of the core trench will be dependent upon site conditions for the removal of highly fractured rock, especially in the area of faults or shear zones that will require foundation treatment. The appraisal designs include a line of pressure grout holes to depths of 40 feet, and quantities for slush grouting and dental concrete treatment.

The central impervious core (zone 1) will have a top elevation 2 feet above the maximum reservoir level. It will have a top width of 15 feet and sideslopes of 0.75 to 1. The placement and compaction requirements will be determined based on the materials to be used. A chimney drain with a 10-foot horizontal width will be provided on the downstream slope of the central core, and will be connected to a 10-foot-thick blanket drain placed on the dike foundation between the core and the downstream toe. The chimney drain will act as a filter to prevent fines migration from the core. A 12-inch perforated toe drain pipe will be provided near the downstream toe to collect the seepage through the dike embankment and foundation. Because of the highly-fractured condition of the bedrock foundation, the depth of the toe drain should be significant (assumed 20 feet).

An outer (zone 2) shell of semipervious to pervious materials will be provided both upstream and downstream of the central core, with the more pervious materials being placed in the downstream portion. The outer slopes will be 2.5:1 on the upstream face and 2:1 on the downstream face. Compaction requirements will be determined based on the materials to be used. Riprap placed on a bedding layer will be provided to protect the upstream shell against wave action. Each reservoir dike will be completed with suitable instrumentation for future monitoring.

Table 6. - Design Characteristics of Reservoir Dikes

Item	Centimudi Dike	Bridge Bay Dike	Jones Valley Dike	Clickapudi Creek Dike
Est. Ground Elev. at Max. Section (feet)	1200	1233	1055	1063
Foundation Elev. at Max Section (feet)	1195	1230	1050	1060
Max. Str. Height to Crest El. 1290 (feet)	95	60	240	230

Crest Length at El. 1290 (feet)	629	440	1710	1519
Left Abutment Geology	C. Greenstone. Intensely weathered to decomposed.	Hard granitic rock. Lightly to moderately weathered. Intensely to moderately fractured.	Metasedimentary rock. Moderately weathered. Intensely to moderately fractured.	Metasedimentary rock. Intensely weathered. Intensely fractured.
Right Abutment Geology	B. Metarhyolite C. Greenstone. Faulted.	Same as above.	Same as above.	Same as above.
Geology at Max. Section	Balaklala Metarhyolite. Lightly weathered. Intensely to moderately fractured.	Same as above.	Same as above.	Same as above.

XII. CONSTRUCTION MATERIALS

A. Concrete Aggregates

Potential sources of concrete aggregates located within 30 miles of Shasta Dam that have been previously tested and approved by Reclamation are shown on figure 4. All sources tested are suitable for use in concrete, provided proper gradings are obtained and low-alkali cement is used. Since 12 of the 13 identified aggregate sources were tested over 30 years ago, further investigations of these sources should be performed prior to feasibility-level designs. The Damsite and Structure Review Team Report [4] identified the Clear Creek dredge tailings located 16 miles south of Shasta Dam, and alluvial deposits along the East Fork of Stillwater Creek located 6 to 8 miles southeast of Shasta Dam, as additional potential sources of concrete aggregates.

Suitable concrete aggregate sources should be identified to meet both concrete quality and quantity requirements. The estimated concrete quantities for the Shasta Dam modifications total 7,775,000 yd^3 for the high dam raise option, 3,491,000 yd^3 for the intermediate dam raise option, and 52,000 yd^3 for the low dam raise option. Aggregates proposed for RCC construction should generally meet the mass concrete quality requirements. Maximum aggregate sizes assumed for the current studies are 4-inches for mass concrete and 3-inches for RCC.

B. Embankment Materials

Required excavation for the abutment wing dams and upstream cofferdams will include the removal of portions of the existing embankment sections on both abutments, which consists of upstream rockfill graded to heavy rock at the upstream face (zone 1); semi-pervious material

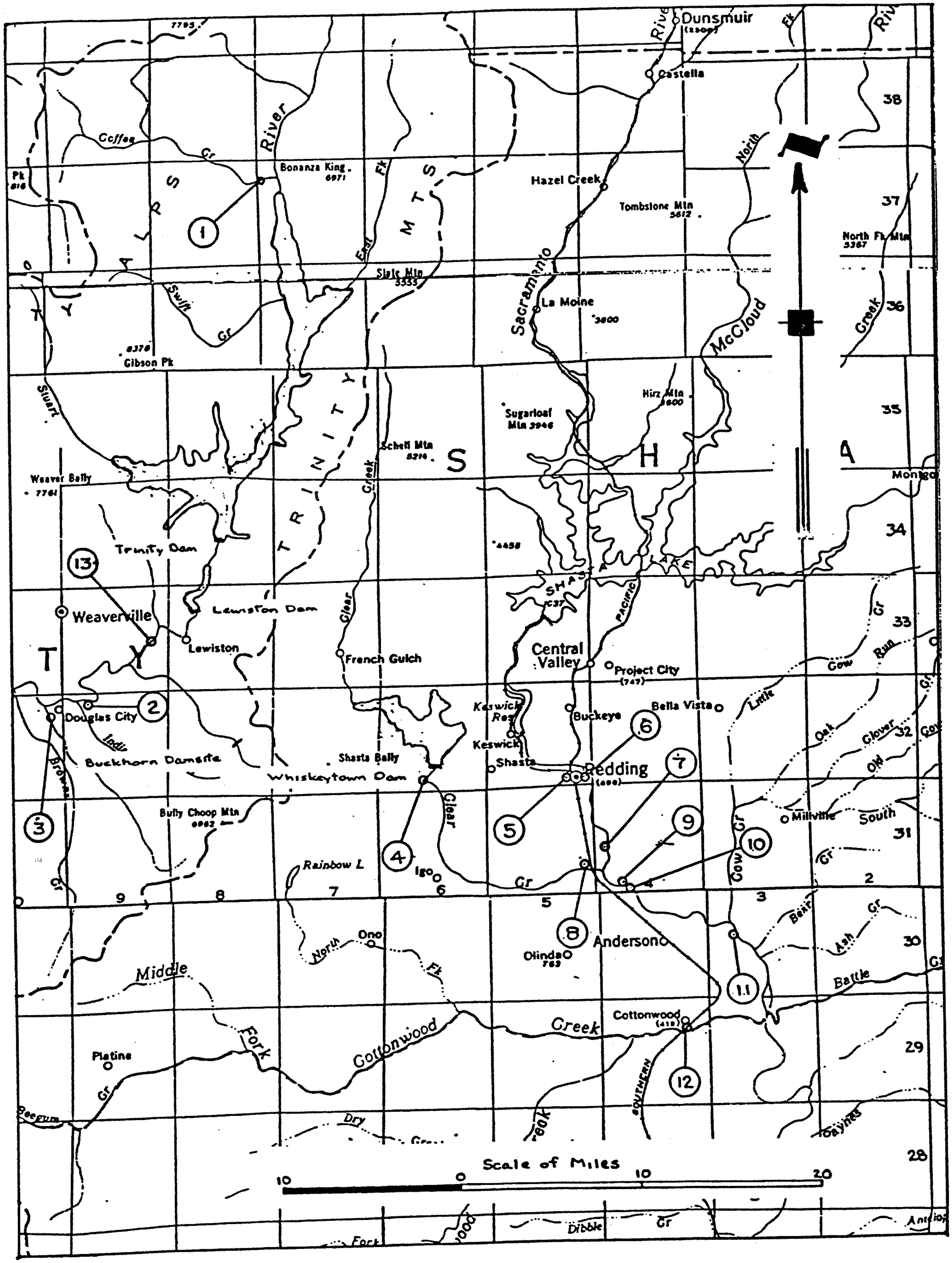

FIGURE 4 - CONCRETE AGGREGATE SOURCE LOCATION MAP

(zone 2); selected impervious material of clay, sand, and gravel (zone 3); selected rock and clay materials (zone 4); and downstream rockfill graded to coarse rock at the downstream face (zone 5). Additional excavation will include surficial materials and intensely weathered rock on both abutments, and more competent rock at the new powerplant site. Total required excavation is 4,864,000 yd^3 for the high dam raise option and 3,734,000 yd^3 for the intermediate dam raise option. Some of these materials may be used at the damsite for temporary cofferdams, channel slope protection, and to provide a foundation for the new switchyards. The upstream cellular cofferdams will require 185,000 yd^3 of free-draining materials for backfill.

No new investigations have been performed to locate appropriate borrow sources for construction of the reservoir dikes. Total embankment quantities for the high dam raise option include 2,435,850 yd^3 of impervious (zone 1) materials; 3,944,240 yd^3 of shell (zone 2) materials; 384,810 yd^3 of drain materials; 148,010 yd^3 of riprap, and 74,010 yd^3 of bedding materials. Total embankment quantities for the intermediate dam raise option include 579,300 yd^3 of impervious materials; 836,700 yd^3 of shell materials; 124,450 yd^3 of drain materials; 43,370 yd^3 of riprap, and 21,800 yd^3 of bedding materials. Impervious materials for the Centimudi and Bridge Bay Dikes may be available from local deposits of clayey residual soils in the Bass Mountain area between Shasta Dam and Interstate 5. Impervious materials for the Jones Valley and Clickapudi Creek Dikes may be available from small, decomposed granitic bodies within 1 mile of each site [4]. Additional impervious material sources may be found within the reservoir area. Shell, riprap, and bedding materials may come from required excavation for Shasta Dam, or from quarry sites closer to the dikes. Drain materials may come from concrete aggregate sources. For the current studies, all embankment materials were assumed to come from borrow sources within 5 miles of the reservoir dike sites.

XIII. TRANSPORTATION ROUTE RELOCATION FEATURES

A. Pit River Bridge Modifications

Maximum reservoir levels for the low dam raise option will require modifications to the existing Pit River Bridge, shown on figure 5. Flood proofing of the lower steel truss members at piers 3 and 4 will be required to protect against possible corrosion and floating debris during submergence, for water levels above elevation 1067. The estimated cost to apply epoxy paint, enclose support bearings, and install steel trash deflectors for protection to elevation 1084 is about $1 million. This will provide a minimum of 14 feet of clearance below the bridge for boat traffic during the PMF. No detailed cost estimates were prepared for this work.

B. Pit River Bridge Replacement Alternatives

Maximum reservoir levels for the high and intermediate dam raise options will require the construction of a new bridge for Interstate 5 and the Southern Pacific Railroad. The proposed eastern crossing site located 200 feet east of the existing bridge was assumed for this study. The new bridge is proposed to be designed to higher standards, including 6 traffic lanes, inside and outside shoulders for each direction, a center median, and sidewalks, for a total deck width of 110 feet. The width of the existing bridge deck is less than 52 feet. A railroad bridge deck beneath the highway deck would be provided (as for the existing bridge) with a 35-foot width. The bridge piers would be constructed in the dry with the reservoir at or below elevation 1010. The high dam raise option would require a suspension bridge with a main span of 2,700 feet, and end spans of 900 feet, at deck elevation 1360. A suspension or cable-stayed bridge having the required dimensions is considered within the current engineering state-of-the-art. (A suspension bridge with a 95-foot-wide highway deck above a light rail line is now under construction in Japan, with a main span of 6,527 feet and a total length of 12,825 feet. Completion is expected later this year. The Golden Gate Bridge in California has a main span of 4,200 feet and a deck width of 90 feet.)

The estimated field cost for this bridge (without approaches) is based on a preliminary estimate of $600/ft^2$ for the main span and $300/ft^2$ for the end spans, with an allowance of 15 percent for unlisted items and 25 percent for contingencies, and is approximately $340 million. These unit prices are based on estimates provided by Figg Engineering of Tallahasee, Florida, and by TY Lin International of San Francisco, California, based on their experience with recently designed and/or constructed long multi-span bridges in the United States. A price adjustment for the added railroad structure below the highway deck was based on the additional steel frame required for the railroad structure, and on the heavier steel members that would be required for the overall structure. The previous field cost for a new bridge at this site (using the same allowances for unlisted items and contingencies) is about $366 million in April 1984 prices (described as an "order of magnitude" estimate at the time), which would translate to about $548 million in current dollars. This is a significant difference, and should be investigated further for the feasibility-level designs. Also, the added cost to provide a wider highway deck than for the existing bridge should probably not be considered a dam raise cost.

No reduction in estimated construction cost for the intermediate dam raise option was made, due to the uncertainty of the cost estimates for the bridge.

C. Transportation Route Relocations

Enlargement of Shasta Dam would require the relocation of both the Interstate 5 highway and the Southern Pacific railroad, both of which cross Shasta Lake. Raising the lake level 200 feet will require the relocation of about 35 miles of the railroad and 17 miles of the highway. These relocations represent a very large portion of the overall project cost, and were only evaluated to a reconnaissance level by the California Department of Water Resources (DWR) in 1984 [1]. DWR recommended that CALTRANS perform future feasibility-level designs and estimates for both the new highway and the Pit River Bridge. Such studies are important to refine these preliminary cost estimates, which have been indexed more than 5 years in violation of current Reclamation policy.

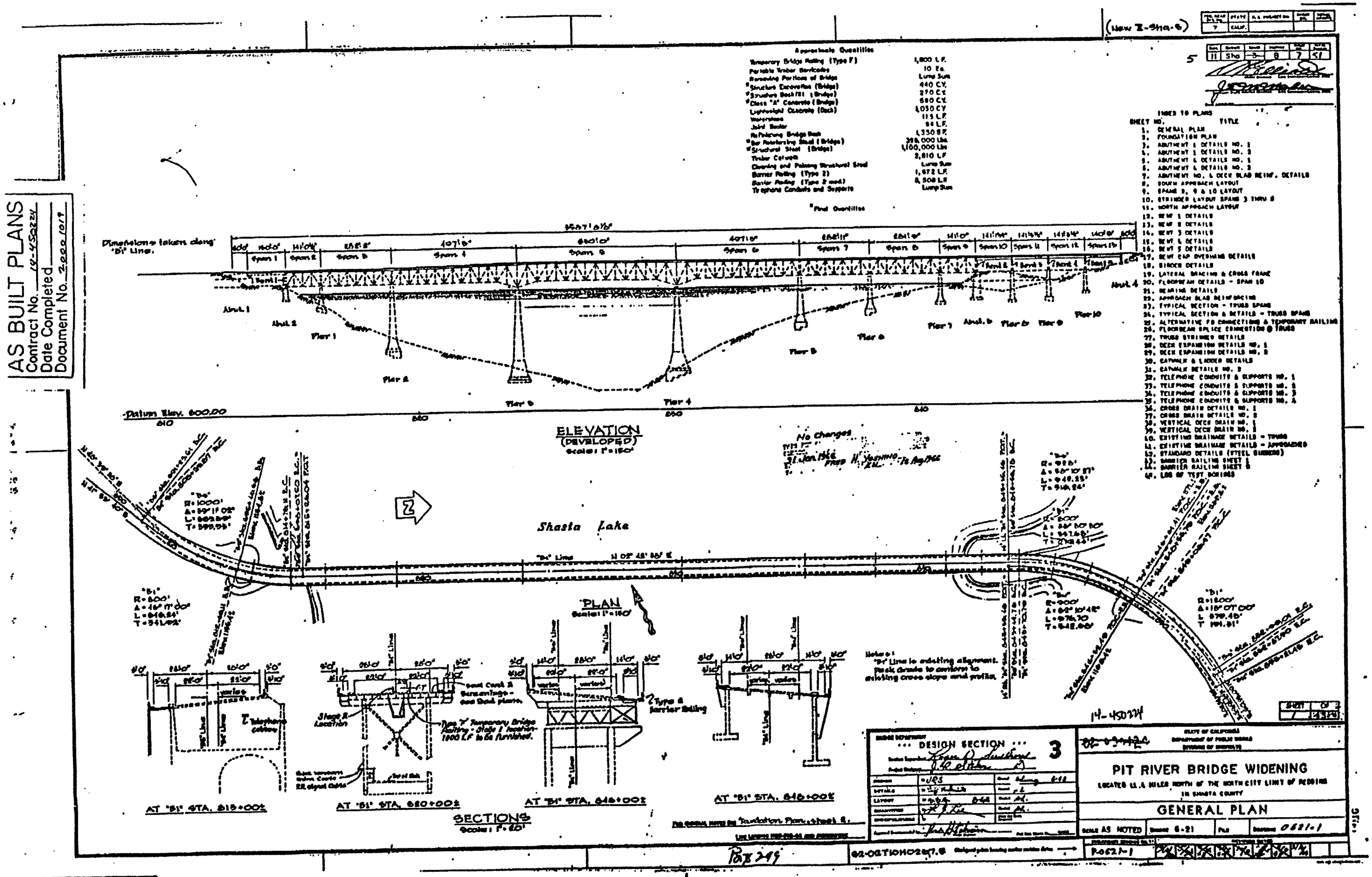
AS BUILT PLANS
Contract No. 14-45C224
Date Completed
Document No. 2000 1019
ELEVATION
(DEVELOPED)
Scale: 1" = 150'
Shasta Lake
PLAN
Scale: 1" = 150'
SECTIONS
Scale: 1" = 20'
AT "B1" STA. 815+00±
AT "B1" STA. 820+00±
AT "B1" STA. 846+00±
AT "B1" STA. 848+00±
Approximate Quantities
INDEX TO PLANS
DESIGN SECTION
3
PIT RIVER BRIDGE WIDENING
GENERAL PLAN
SCALE AS NOTED
14-450774

FIGURE 5

XIV. KESWICK DAM AND POWERPLANT MODIFICATIONS

Modifications to Keswick Dam and powerplant would be required to increase the storage capacity of Keswick Reservoir if increased releases are made from the new Shasta powerplant for peaking power. Enlargement of the reservoir would be achieved by either increasing the height of the existing dam by up to 25 feet, or by construction of a new concrete structure about two miles downstream. Preliminary designs and estimates for an enlarged Keswick Dam were prepared in 1982, and provide the basis for indexed costs used for this study. Preliminary designs and estimates for a new Keswick powerplant were prepared by Bookman-Edmonston Engineering in 1996. Appraisal-level designs for an enlarged and/or new dam and powerplant should be prepared after the need for an enlarged afterbay reservoir has been determined. It should be noted that raising the existing Keswick Dam would increase tailwater levels at both Shasta Dam and Spring Creek Debris Dam, reducing power generation capacity and requiring additional structural modifications at both powerplants to prevent flooding.

XV. OTHER PROJECT FEATURES

Other project features associated with raising Shasta Dam include resort relocation and land rights, public recreation relocation, reservoir clearing, recreation facilities, and Sacramento River seepage mitigation. Preliminary costs for each of these items were prepared by others in 1982, for reservoir levels at elevations 1270 (14.3 MAF alternative) and 1130 (6.75 MAF alternative). For the current studies, the costs for the 14.3 MAF alternative were used for the high dam raise option (crest elevation 1280), and the costs for the intermediate dam raise option (crest elevation 1180) were approximated by linear interpolation between the elevation 1130 and 1270 costs for each item. All costs were then indexed to current price levels for this study.

All recreational campgrounds and resorts are currently above elevation 1085, and should not be affected by the low dam raise option. Potential costs for land rights, reservoir clearing, and Sacramento River seepage mitigation for the low dam raise option were approximated using the costs for the 14.3 MAF and 6.75 MAF alternatives, and assuming zero costs for the existing conditions. The reservoir clearing and seepage mitigation costs appeared to be a linear relationship with reservoir elevation. These assumptions are very preliminary, and would have to be confirmed by additional studies.

XVI. CONSTRUCTION COST ESTIMATES

A. General

Detailed construction cost estimates were prepared for the appraisal-level design features included in this study, based on current unit prices. These design features include the concrete dam overlay and RCC wing dams, spillway, river outlets, TCD modifications, selective-level intake, penstocks, new powerplant, switchyards, cellular cofferdams, and reservoir dikes. All appraisal-level estimates include an allowance for unlisted items of 10 or 15 percent, and an allowance for contract contingencies of 25 percent. A higher allowance for unlisted items of 15 percent was used for the concrete dam to cover a potential uncertainty in the concrete quantities, and a higher mobilization cost (10 percent) was assumed for the extensive concrete batching and delivery systems required. Cost estimate worksheets for these features are provided in Appendix D.

Additional project features estimated by others in 1996 (copy provided by the MP Regional Office) have been indexed to current price levels to provide an estimate of total project costs for each dam raise option. These features include the relocations for the Interstate 5 highway and the Southern Pacific railroad, potential modifications to Keswick Dam and powerplant, resort relocations, land rights, reservoir clearing, recreation facilities, and Sacramento River seepage mitigation. A preliminary cost for a new Pit River Bridge (or Bridge Bay Crossing) was developed for this study as discussed in Section XIII. These features have only been evaluated to a reconnaissance level, but represent nearly one-half of the total project costs for both the high and the intermediate dam raise options. Furthermore, it is Reclamation policy not to index any prices over 5 years old. Cost estimate worksheets for these features are provided in Appendix D. Appraisal-level designs and estimates should be prepared for these features for future studies.

The construction cost estimates prepared for this study represent field costs for each dam raise option, and do not include additional costs for design data collection, engineering, contract administration, and construction management. Previous Shasta studies by DWR assumed an engineering cost of 4.5 percent and a contract administration cost of 23 percent, for a total additional cost of 27.5 percent [1].

B. Field Cost Summaries

Estimated field costs for the three dam raise options included in this appraisal-level study are summarized in table 7 below. The detailed cost estimate worksheets for each option are provided in Appendix D.

Table 7. - Field Cost Summaries for Dam Raise Options

Description	Crest El. 1084	Crest El. 1180	Crest El. 1280
Cofferdams	$ 0	$ 29,000,000	$ 29,000,000
Structure Removal	7,200,000	11,000,000	11,000,000
Concrete Dams	15,500,000	550,000,000	1,100,000,000
Spillway	22,000,000*	17,500,000	24,000,000
River Outlets	15,500,000	58,000,000	80,000,000
Existing Powerplant	10,500,000**	57,000,000	80,000,000
New Powerplant	0	473,000,000	510,000,000
Switchyards	0	60,300,000	114,300,000
Reservoir Dikes	0	28,900,000	98,000,000
SUBTOTAL A	$ 70,700,000	$ 1,284,700,000	$ 2,046,300,000
Keswick Dam & PP	0	0	253,000,000
Pit River Bridge	1,000,000	340,000,000	340,000,000
I-5 Relocation	0	181,190,000	235,050,000
SPRR Relocation	0	353,000,000	455,000,000
Reservoir Clearing	3,000,000	24,000,000	46,000,000
Resort/Land Rights	5,000,000	59,000,000	77,000,000
Rec. Relocation	0	210,000,000	210,000,000
Rec. Facilities	0	48,000,000	57,000,000
Seepage Mitigation	3,000,000	43,000,000	86,000,000
SUBTOTAL B	12,000,000	$ 1,258,190,000	$ 1,759,050,000
GRAND TOTAL	$ 82,700,000	$ 2,542,890,000	$ 3,805,350,000

* Includes mass concrete in spillway crest (included in dam for other options).
** Includes field cost of modifications to temperature control device.

C. Field Cost Curve

Estimated total field costs for the appraisal-level design features included in this study (Subtotal A, table 7), and for the other project features (Subtotal B, table 7), for the three dam raise options considered, are summarized in table 8 below. The total field costs are also divided by the increase in reservoir storage provided by each dam raise option (from table 4), to produce an average cost per acre-foot of additional storage (not reservoir yield) for each option. Additional costs for design data collection, engineering, contract administration, and construction management are not included.

Table 8. - Total Field Costs and Average Costs Per Acre-Foot of Storage

Description	Crest El. 1084	Crest El. 1180	Crest El. 1280
Dam Features (A)	70,700,000	1,284,700,000	2,046,300,000
Other Features (B)	12,000,000	1,258,190,000	1,759,050,000
Total Field Cost	$ 82,700,000	$ 2,542,890,000	$ 3,805,350,000
Added Storage (a-f)	290,000	3,920,000	9,340,000
Cost Per Acre-Foot	$ 285	$ 649	$ 407

The total estimated field costs for the dam features alone, and for all project features, for each dam raise option, are plotted on figure 6. While these data points have been plotted as a smooth curve for these appraisal-level estimates, discrete jumps should be expected at various points where significant cost increases would occur. These primarily include the points between elevations 1084 and 1180 for which the new powerplant and switchyard would be constructed; the I-5 and SPRR relocations would be required (including replacement of the Pit River Bridge); the recreation facilities relocations would be required; the left abutment cofferdam would be constructed to remove the existing left wing dam; and the dam crest raise would require an overlay on the downstream face for stability. Significant points between elevations 1180 and 1280 include the elevations for which modification or replacement of the existing Keswick Dam and powerplant would be required, and for construction of the Centimudi and Bridge Bay Dikes.

XVII. CONSTRUCTION CONSIDERATIONS

Preliminary indications are that required construction activities to raise Shasta Dam may take 8 to 10 years for the maximum proposed raise to crest elevation 1280, and may cost over $2 billion for the dam features alone. Financial considerations may force the division of project work into separate contracts spread out over a long period of time. Dam features which may be considered for construction under separate contracts (apart from the prime contract) include the reservoir

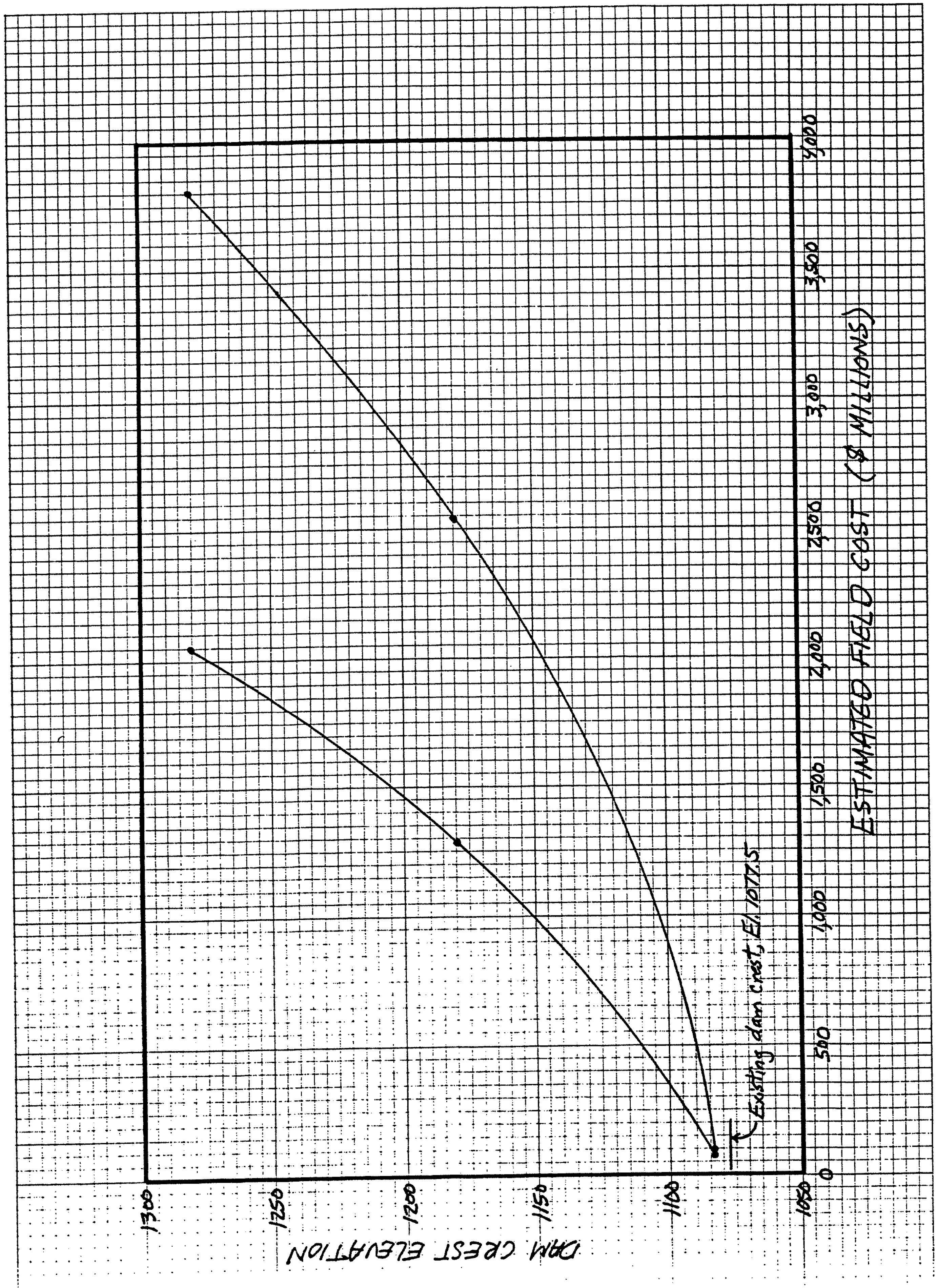

FIGURE 6 - FIELD COST CURVE FOR DAM RAISE OPTIONS

dikes, the 230 kV switchyard, the 525 kV switchyard, the new powerplant, and the upstream cellular cofferdams. The left abutment cofferdam will require lower reservoir levels for construction than is expected under average conditions, but may be constructed early if reservoir levels are expected to be low before the prime contract will be awarded. The 230 kV switchyard should be completed before construction for the new powerplant begins, while the 525 kV switchyard will not be needed until several years later, when the new powerplant is completed and operational. A separate contract for the new powerplant could extend to a penstock connection point identified in the prime contract. The reservoir dikes are located several miles from Shasta Dam and would be easily separated, even if some construction materials are developed from required excavation under the prime or other contracts. Although the remaining heavy construction work for the dam raise, spillway, river outlets, power outlets, and penstock intakes would not be easily divided, the larger mechanical items could be included under separate supply contracts to reduce the cost of the prime contract.

Additional discussion of construction considerations, sequence, and durations is being developed by the Willows Construction Office.

XVIII. FUTURE DESIGN CONSIDERATIONS

A. Design Data Requirements for Future Studies

The following design data should be collected for preparation of future feasibility-level designs. Formal geologic data collection requirements for feasibility-level designs are to be determined at a later date.

1. Surface mapping and topography (with 2- or 5-foot contour intervals) at the four reservoir dike sites.

2. Reassessment of construction material availability for concrete aggregates and dike embankments.

3. Operation study results relating to the need for enlargement of Keswick Reservoir. If a new dam or dam raise is needed, surface mapping and topography (with 2-foot contour intervals) should be provided, and a field exploration program may be required.

4. Revised PMF and frequency floods using HMR 58 and current hydrologic data.

5. Revised tailwater curve for stilling basin/tailrace area below dam, to 280,000 ft^3/s. Existing tailwater data are shown on drawings 176-WFA-001 to 80,000 ft^3/s (based on operational data) and on 214-D-704 to 250,000 ft^3/s (based on original design assumptions).

6. Disposal site locations for excavated materials, waste concrete, and miscellaneous mechanical and electrical equipment (including hazardous materials).

7. Design discharge for new powerplant and/or powerplant power output requirements.

8. Reservoir operations data which identify the extent of reservoir level variations for normal to extreme conditions, with time of occurrence information, to fully evaluate hydroelectric generation capabilities and specific design requirements.

9. As-built records of the left abutment embankment construction, indicating foundation excavation contours (especially at the concrete core wall), and embankment material gradations and zone contacts, if available. If not available, a field exploration program will be required.

B. Potential Value Engineering Alternatives

The following ideas surfaced during the course of the current appraisal-level study, and should be considered for a future value engineering study of the project.

1. Use RCC in main dam section. - Future studies should evaluate the feasibility of using RCC for the entire dam raise, rather than limiting its use to the wing dams on both abutments. Significant cost savings may be possible by constructing the dam raise in 1-foot lifts rather than in blocks, without cooling coils and grouted contraction joints. Design and construction details for the massive, curved RCC dam section, with numerous outlet pipes and galleries, would have to be identified. The use of RCC may also facilitate the construction of a stepped chute for the spillway section.

2. Construct underground powerplant. - The potential for construction of an underground powerplant within the left abutment bedrock should be considered, to avoid the large open-cut rock excavation required for the current design, and to preserve the existing switchyard. The new penstocks could also be constructed within tunnels from the powerplant to an upstream lake tap intake.

3. Reduce size of penstocks for existing powerplant. - The installation of smaller diameter steel linings within the existing penstocks should be considered, to avoid concrete excavation within the dam. Installation of a 14-foot-diameter lining would increase flow velocities by about 15 percent, compared to the existing 15-foot-diameter penstocks, resulting in additional head loss and reduced power generation, but for a smaller construction cost. Lining of the spiral case for each unit, to accommodate the higher reservoir heads, could eliminate the need for the butterfly isolation valves.

4. Reduce size of penstocks for new powerplant. - An economic analysis should be performed to size the penstocks for the new powerplant. Smaller diameter steel pipes

would reduce the concrete excavation requirements through the dam, and permit the use of a smaller upstream fixed-wheel gate. A smaller isolation valve could also be used, if they become a requirement for the new powerplant (although not included in the current studies).

5. Replace turbines in existing powerplant. - Installation of new turbines within the existing powerplant, and replacement of the existing spiral cases, would permit a higher power output and possibly eliminate the need for the large isolation valves required for the high dam raise option. The turbine flow requirements would have to be evaluated to determine whether the existing TCD would have to be modified in operation or design, or be replaced with a new structure designed for the higher operating head and flow velocities. This was partially explored for the previous studies, but did not address all potential impacts to the existing powerplant structure.

6. Increase operating range of both powerplants. - If the power generating capability is to be increased at Shasta Dam, the operating range of both powerplants should be increased as much as possible. The use of either variable-speed turbines with variable-frequency generator units, or two-speed turbine-generator units, should be investigated for their viability at this site. It may prove preferable to operate all generating units from the highest reservoir level down to the lowest anticipated reservoir level, as opposed to having to take a complete powerplant off-line when a particular reservoir level is reached. However, the use of the existing powerplant structure for installation of the larger "multi-speed" turbine-generator units may not be possible without substantial modifications. Potential powerplant structure alternatives would then need to be investigated. Lower penstock intake elevations should also be considered.

7. Consider gate alternatives for river outlets. - Further studies should be made to optimize the type and size of the river outlet gates. The current studies assumed the existing gates would either be retained or replaced, but structural modifications to the existing gates may be possible to permit their operation under higher reservoir heads. Other types of gates may be found to be more economical considering the concrete excavation and installation requirements. The decision to replace all tube valves for the low dam option could also be reconsidered. Any proposed changes must consider the impact on reservoir evacuation capability, however.

8. Consider gate alternatives for spillway. - The spillway radial gates assumed for the current study were originally selected for the 1978 dam raise study. Two of the drum gates at Friant Dam in California have been replaced by 100-foot-long by 18-foot-high Obermeyer crest gates. Crest gates or other gate alternatives, such as top-seal radial gates, should be considered for the Shasta Dam raise. Increased flood storage and reduced spillway discharge capacity should also be evaluated for hydraulic considerations in the chute and stilling basin.

9. Upstream cofferdam alternatives. - RCC should be considered as an alternative to the proposed upstream cellular cofferdams. Such construction may be considered as a "test section" for RCC construction for the dam. The required crest elevation for the cofferdams should also be evaluated.

10. Relocate isolation valves. - If isolation valves are determined to be necessary for the existing powerplant, an alternative location at the toe of the dam should be investigated. Installation of the isolation valves at the connection point between the new penstocks through the dam and the existing penstocks to the powerplant, with valve vaults incorporated within the concrete overlay for the dam, would facilitate construction, reduce the design head for the large isolation valves, and provide an additional emergency closure capability for the exposed penstocks in the event of damage or rupture.

REFERENCES

[1] Summary Report - Enlarged Shasta Lake Investigation, California Department of Water Resources, Sacramento, California, September 9, 1988.

[2] Decision Memorandum No. SD-MDA-DM-3110-93-2, Subject: Modification Decision Analysis (Hydrologic/Hydraulic and Structural Supplement) - Shasta Dam - Central Valley Project, California; Bureau of Reclamation, Denver, Colorado, September 30, 1993.

[3] ACER Technical Memorandum No. 3, Subject: Criteria and Guidelines for Evacuating Storage Reservoirs and Sizing Low-Level Outlet Works; Bureau of Reclamation, Denver, Colorado, August 1990.

[4] Enlarging Shasta Lake Feasibility Study - Damsite and Structure Review Team Report, Bureau of Reclamation, Mid-Pacific Region, December 1982.

[5] Memorandum to the Technical Files from Joel F. Sturm, Geologist, Subject: Summary of Drilling Investigations for Enlarged Shasta Dam - January-June 1984 - Enlarged Shasta Lake Feasibility Investigation - Central Valley Project, California, Bureau of Reclamation, Sacramento, California, November 19, 1984.

[6] E-mail to Tom Hepler from Karen Weghorst, Subject: Flood Volumes for Shasta, Bureau of Reclamation, Denver, Colorado, February 18, 1998.

[7] Report of Findings - Comprehensive Facility Review for Shasta Dam - Central Valley Project, California, Bureau of Reclamation, Denver, Colorado, February 1998.

[8] Standing Operating Procedures for Shasta Dam and Lake - Central Valley Project, California, Bureau of Reclamation, Mid-Pacific Region, Shasta Office, August 1991.

APPENDICES

A. Structural Analysis Results

B. Hydraulic Analysis Results

C. Extended Reservoir Capacity Data

D. Cost Estimate Worksheets

1. Shasta Dam Enlargement - Elevation 1280
2. Shasta Dam Enlargement - Elevation 1180
3. Shasta Dam Enlargement - Elevation 1084

E. Appraisal Design Drawings

1. 214-D-23982 Plan, Profiles, and Sections - Crest El. 1280 - Appraisal Design, Sheet 1 of 3.
2. 214-D-23983 Plan, Profiles, and Sections - Crest El. 1280 - Appraisal Design, Sheet 2 of 3.
3. 214-D-23984 Plan, Profiles, and Sections - Crest El. 1280 - Appraisal Design, Sheet 3 of 3.

APPENDIX A

BUREAU OF RECLAMATION

Technical Service Center, Denver, Colorado

Technical Memorandum No. SHA-8110-TM-98-01

Region: Mid-Pacific

Project: Central Valley, California

Feature: Shasta Dam

Subject: Analyses for the Proposed Raise of Shasta Dam to Elevation 1280.0, and for the Proposed 300-foot High RCC Gravity Wing Dams

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Prepared by: F. J. Jackmauh 3/2/98
F. J. Jackmauh, D-8110

Checked by: Larry K. Nuss

Noted: Thomas E. Hepler 3/2/98
Team Leader — Date

Peer Review: Larry K. Nuss 3/2/98
Larry Nuss, D-8110 — Date

REVISIONS		SURNAMES				
Date	Description	Prepared	Checked	Technical Approval	Peer Review	Noted

SHASTA DAM - APPRAISAL DESIGNS

Summary

As requested by the Mid-Pacific Regional Office, appraisal level analyses for the raising of Shasta Dam approximately 200 feet, to elevation 1280.0, and the analysis of a 300-foot high maximum section roller compacted concrete (RCC) gravity dam were performed. The geometry initially used for the analyses was taken from designs used for the previous 1985 appraisal level analyses and found on Drawing 214-D-21946, Shasta Dam Modification, Plan and Sections - Top of dam El. 1280.0 (see Figure 1). Each design was analyzed for the static loads of gravity, reservoir, and uplift pressures using Reclamation stability criteria for gravity dams. Upon examination of these results, it was found the originally proposed maximum section with a downstream slope of 0.60:1 developed tensions at the heel of the structure under the static loading condition, and that in subsequent dynamic analyses these tensions would only lead to higher tensile stresses. A proposed downstream slope of 0.70:1 was then decided to be used for the static and dynamic finite element analyses.

This memorandum describes the proposed shape of the raised dam and new RCC wing sections, the method of analyses, the material properties used, the results obtained, and recommendations concerning portions of these designs which will require additional investigations as the design process proceeds.

1.0 Introduction

Shasta Dam is the northern outpost of the Central Valley Project of California, and is situated on the Sacramento River approximately 12 miles north of Redding, California. Shasta stores the spring run-off, releasing it as needed throughout the year for irrigation in the Sacramento Valley and for transfer as supplemental water to the San Joaquin valley. In addition, Shasta Dam develops power for use in the comprehensive Central Valley Project scheme.

The Shasta Reservoir is 35 miles long and covers a surface area of 46 square miles. Of the 4,493,000 acre-feet total storage capacity, 104,000 acre-feet is inactive storage and 500,000 acre-feet is reserved for flood storage.

Shasta Dam is a concrete gravity dam with a 375-foot long straight spillway section occupying the old river channel, flanked by non-overflow sections curved on 2,500-foot radii. This shape most economically fit the configuration of the ridges forming the dam site. The dam has a total crest length of 3,500 feet and maximum height of 602 feet from bedrock to crest (based on the depth of foundation treatment). The width to height ratio of 5.8 is relatively high and is disproportionate for an economical arch dam. The left abutment was not strong enough to support the heavy thrusts from arch action. Accordingly, while the dam is curved at the abutments in plan to accommodate the site topography, Shasta was designed as a gravity structure throughout, resisting hydrostatic loads of the reservoir by its weight. However, since the dam is curved, some level of arching action will develop. This arching action improves the stability and load carrying capacity of the dam.

1.1 Purpose

The purpose of this Technical Memorandum (TM) is to document the analyses performed, at an appraisal level, for the possible raise of the existing Shasta Dam to the crest elevation of 1,280.0 feet, and of the proposed gravity RCC wing dams to a maximum height of 300 feet. The geometry used for these analyses was obtained from Drawing No. 214-D-21946, Shasta Dam Modification, Plan and Sections - Top of Dam El. 1280.0, and is included in this document as Figure 1.

2.0 Model Preparation and Analyses

This section describes the assumptions and simplifications made for development of practical and economical finite element models representing the maximum section of the proposed design of both the enlarged Shasta Dam and the RCC gravity wings.

2.1 Material Properties

Material properties and other assumptions used in these analyses were the same as those that were used in the 1978 appraisal level analyses for the increase of height of Shasta Dam to elevation 1270.0 [1], with the exceptions noted with an *, and are presented here:

1. Top of dam, Elevation 1280.0 (presently 1077.5)
2. *Base of maximum section, elevation 510.0
3. *Normal reservoir, elevation 1280.0
4. *Minimum tailwater level, elevation 510.0
5. Unit weight of mass concrete, 154 lb/ft^3
6. Average strength of concrete at 1 year, 5000 lb/in^2
7. Assumed coefficient of friction for concrete and rock, 1.0
8. Unit cohesion for concrete and rock, 600 lb/in^2
9. Sustained modulus of elasticity of concrete, 3.0 x 10^6 lb/in^2
10. *Dynamic modulus of elasticity of concrete, 5.0 x 10^6 lb/in^2
11. Poisson's ratio for concrete, 0.20
12. Modulus of deformation for foundation rock, 2.0 x 10^6 lb/in^2
13. Poisson's ratio for foundation rock, 0.25
14. Silt accumulation, if any, not included
15. Unit weight of water, 62.4 lb/ft^3
16. *Unit weight of RCC, 150 lb/ft^3
17. *Sustained modulus of elasticity of RCC, 3.0 x 10^6 lb/in^2
18. *Dynamic modulus of elasticity of RCC, 5.0 x 10^6 lb/in^2
19. *Poisson's ratio for RCC, 0.20
20. *Damping , 5% of critical
21. *Tensile strength existing (from Raphael , $2.6f'_c{}^{2/3}$), 760 lb/in^2
22. *Tensile strength RCC, 250 lb/in^2

2.2 Applied Loading

Only gravity loads plus full reservoir were considered in the static finite element analyses. Reservoir water surface elevation was taken to be 1280.0 feet. Added mass was accounted for in the dynamic analyses based on Westergaard's theory [2] with the reservoir at elevation 1280.0.

Uplift pressures were included along the base of the dam when calculating the sliding stability of the dam and limit equilibrium stresses. The drains were assumed to have an effectiveness of 0.66, which is a Reclamation standard. Loads included from thermal differentials were not included in the analyses, but should be investigated in further analysis for this raise option. The reason for excluding temperature studies are as follows. First, expansions and contractions of the dam induced by thermal differentials between the dam, reservoir, and ambient air are not as critical in a gravity dam as in an arch dam because of the lack of restraint. Second, temperature induced stresses between the existing concrete and the new concrete overlay is beyond the scope of this level of analysis. These stress conditions can be addressed in the final design phase.

2.2.1 Dynamic Loading

Based on Technical Memorandum No. D8330-96-19, Risk Assessment for Spring Creek Debris Dam, Earthquake Loading Parameters, Central Valley Project, California [4], the following earthquakes in the Richter magnitude range of 5.75 and 6.5 were identified for Shasta Dam:

Recurrence (years)	Annual Probability	PHA (g)	ASI (cm/sec)	VSI (cm)
1000	0.001	0.08	63	22
1500	0.000667	0.10	82	29
2000	0.0005	0.12	97	34
3500	0.000286	0.17	131	47
5000	0.002	0.20	156	55
7500	0.000133	0.24	187	66
10000	0.0001	0.27	211	74
20000	0.00005	0.35	272	96
25000	0.00004	0.37	293	104
50000	0.00002	0.46	362	129
100000	0.00001	0.55	435	157

NOTE: PHA = Peak Horizontal Acceleration
ASI = Acceleration Spectral Intensity, VSI = Velocity Spectral Intensity

The earthquake with the 50,000 year recurrence interval was the one selected for these analyses on the basis of peak horizontal ground acceleration (PHA), acceleration spectral intensity (ASI), and annual probability. The peak horizontal ground motion and vertical motion time histories used for the analyses are the Castaic Record of the Northridge Earthquake of 1994. This record was selected based on the shape of the target response spectrum of the ground motions and the initially assumed fundamental frequency of the proposed modified design of Shasta Dam.

2.3 Initial Stability Analyses

Prior to the construction of the finite element model of the proposed enlargement to Shasta Dam and the 300-foot high RCC wing dams, static stability analyses were conducted using gravity loading, full reservoir, and uplift pressures as the loading condition. The 'in-house' program GRAVDAM [3], was used to determine the static stability and base stresses, and sliding factors of safety. This program also performs a forced crack analysis, based on the material properties given above and Reclamation stability criteria. All input parameters are listed along with the cross section of the dam showing applied loadings; graphical and tabular results are also shown.

2.3.1 Raise to El. 1280.0 - 0.60:1 Slope

Results of this stability check for the 0.60:1 slope, as shown in Figure 2, indicate tensions at the heel of the dam under the static loading condition when uplift is included. In a no tension situation, this would signify that a crack has been formed. Figure 3 shows results of the same analysis, but back-calculates the reservoir water surface for a 'no tension' situation at the heel of the dam, showing that the reservoir water surface could raise no higher than elevation 1210.41 feet before initiating cracking at the base of the dam for this design. Based on the results using this design, it was determined that investigations begin using a 0.70:1 slope .

2.3.2 Raise to El. 1280.0 - 0.70:1 Slope

Figure 4 shows the results of the GRAVDAM stability analysis of a design using a 0.70:1 downstream slope. Graphical output indicate the entire length of the base is in a state of compression while being subjected to the applied loading. This is a more desirable condition than the design using the 0.60:1 slope, as no residual tensile stresses are built in, and that the stresses at the heel are only approaching tensile, a preliminary indication that this is an economical design. A subsequent GRAVDAM stability check shows that through back calculations, the reservoir water surface elevation that produces a 'no tension' situation is 1286.62 feet, now an overtopping situation (Figure 5). These results confirm the fact that the 0.70:1 slope design should be investigated using the finite element method for full static and dynamic loading.

2.3.3 300-foot RCC Wing Dam - 0.80:1 Slope

Figures 6 and 7 show results of the stability analyses for the 300-foot high RCC wing dam. In these analyses, drains were assumed to be located 20 feet downstream of the axis. Results indicate that the entire base of the dam is in the state of compression (Figure 6) and that the reservoir water surface elevation necessary to initiate tensile stresses at the heel is 75.5 feet above the crest of the dam, or elevation 1355.5 feet (Figure 7). These results confirm the adequacy of the 0.80:1 downstream slope design.

2.4 Finite Element Models

The finite element program SAP-IV was used to analyze both the proposed design for the enlargement of Shasta Dam and for the proposed 300-foot high RCC wing dam [3]. Models of both the enlargement design with the 0.70:1 slope and the 300-foot high RCC wing dam and an idealized foundation were built using SAP-IV Type 4 plain strain elements. Figure 8 shows the finite element model used for the enlargement analyses. The foundation extends a distance equal to the height of the dam in directions upstream, downstream, and below the dam. Figure 9 shows only the elements within the dam proper. These elements are grouped into the five sections between the elevations shown, for clarity in later postprocessing results.

Figures 10 and 11 show the finite element model of the 300-foot high RCC wing dam with its idealized foundation, and the finite element model of the dam only, respectively.

2.5 Analysis

Both models were analyzed for the static loading combination of gravity loading and full reservoir loading (El. 1280.0). Results of the dynamic loading condition of the maximum credible earthquake (MCE) of Richter magnitude 6.5 located 8 km from the dam site [5] was then superimposed on the results of the static loading condition to obtain the extreme loading combination.

2.5.1 Analysis - Static - Shasta Dam - El. 1280.0 - 0.70:1 Slope

The model for the proposed enlargement of Shasta Dam to elevation 1280.0 was analyzed using the material properties described above for the static loading combination of gravity and reservoir water surface elevation of 1280.0, only. Uplift pressures were not used in this analysis. The results are shown in Figure(s) 12a through 12e, for the loading condition of gravity loads only. Stresses are output at the centers of each element, and are in the horizontal and vertical directions. The units are in lb/in^2. Positive values signify tensile stresses, negative values, compressive stresses. Similarly, results are shown in Figure(s) 13a through 13e, for the horizontal and vertical stresses due to the reservoir water surface at elevation 1280.0, only. The results of the complete static loading combination of gravity and reservoir water surface elevation at 1280.0 are shown in Figure(s) 14a through 14e. All computed horizontal and vertical stresses within the dam elements are compressive (maximum of 608 lb/in^2), and well within the 5000 lb/in^2 compressive strength of the concrete.

2.5.2 Analysis - Static - 300-foot High RCC Wing Dam

Analysis of the 300-foot high RCC wing dam proceeded in a similar manner. Figure(s) 15a-15b show the horizontal and vertical state of stress within the dam due to gravity loading only; in Figure(s) 16a-16b, due to the reservoir water surface elevation at 1280.0 only; and in Figure(s) 17a-17b, the results of the full static loading combination of gravity and reservoir water surface elevation at 1280.0. As with the proposed enlargement model, all stresses are compressive (maximum of 193 lb/in^2) and are well within Reclamation guidelines for this loading combination and achievable for RCC.

2.5.3 Analysis - Dynamic - Modal Extraction

Prior to performing a complete dynamic time history analysis, a modal analysis must first be undertaken for each model. The modal analysis will calculate the required number of fundamental frequencies of the model that will be used in the time history analysis, and will also aid in the selection of the ground motions used. To account for the dam-reservoir interaction during seismic events, Westergaard's added mass theory is applied to the upstream nodes of each model before calculations are made [2]. The results of these calculations are shown in the table below for the dam raise model, and on the following page for the 300-foot RCC wing dam.

SHASTA DAM - Raise to Elev. 1280.0 - Slope 0.70:1.0
Modal Extraction Results*

Mode Number	No Added Mass		Westergaard's Added Mass	
	Frequency (Hz)	Period (sec)	Frequency (Hz)	Period (sec)
1	**1.450**	**0.6897**	**1.058**	**0.9451**
2	2.739	0.3650	2.382	0.4199
3	3.225	0.3101	2.712	0.3687
4	5.446	0.1836	4.151	0.2409
5	8.251	0.1212	6.181	0.1618
6	9.163	0.1091	8.003	0.1250
7	11.31	0.08845	8.442	0.1185
8	12.57	0.07955	9.536	0.1049
9	13.57	0.07369	10.53	0.09496
10	14.21	0.07040	10.68	0.09367
11	15.99	0.06254	11.66	0.08576

12	17.05	0.05864	12.18	0.08209
13	18.23	0.05484	12.72	0.07861
14	20.05	0.04987	13.63	0.07338
15	20.69	0.04833	15.05	0.06646

SHASTA DAM - 300-foot High RCC Wing Dam
Modal Extraction Results*

Mode Number	Westergaard's Added Mass	
	Frequency (Hz)	**Period (sec)**
1	**3.019**	**0.3313**
2	6.859	0.1458
3	7.686	0.1301
4	10.53	0.0950
5	11.36	0.08804
6	11.50	0.08693
7	14.17	0.07056
8	14.91	0.06708
9	15.61	0.06406
10	16.61	0.06021
11	17.95	0.05571
12	18.99	0.05266
13	21.04	0.04753
14	21.41	0.04671
15	21.96	0.04554

Note: Based on SAP-IV 2-Dimension Type 4 Elements, and a Massless Foundation.

2.5.4 <u>Maximum Credible Earthquake (MCE)</u>

The acceleration response spectrum for the Castaic record of the 1994 Northridge, California earthquake is shown in Figure 18. This record was chosen based on the initial assumption that the fundamental frequency of the proposed modification to Shasta Dam would be between 3 and 7 Hz which would permit approximate maximum response of the model to the ground motions. Modal extractions show that the fundamental frequency was 1.05 Hz, lower on the targeted response spectrum curve, and surely removed from the area of maximum response. This fundamental of the proposed raise, though, is sensitive to the longer period, shorter frequency component of this ground motion, and therefore, this ground motion is deemed suitable for this analysis. Also, the fundamental frequency of the 300-foot RCC Wing dam (3.02 Hz) is close to the maximum response period of this ground motion. Superimposed on this diagram are the fundamental frequencies of the proposed raise with and without added mass (for comparison purposes, only) and the 300-foot RCC wing dam. Because the maximum response of the proposed raise is greater than the targeted response of the ground motions, a factor of 0.80 was applied to each of the ground motion components, bringing the peak horizontal acceleration to a value of 0.33 g and the vertical to 0.17 g. Ground motion time histories and acceleration response spectra at 5 percent damping are shown in Figure 19.

2.5.5 Analysis - Dynamic -Stresses - Shasta Dam - El. 1280.0 - 0.70:1 Slope

The proposed Shasta Dam enlargement model was subjected to a two-component (horizontal and vertical) ground motion time history, with a time step of 0.02 seconds. Damping was assumed to be five percent of critical. Results were superimposed to the results of the static loading combination of gravity and reservoir water surface of 1280.0 feet. Elements from several different portions of the dam were investigated, based on their specific location within the geometry of the dam. These sections included the base of the dam in contact with the foundation rock, the row of elements above Elevation 720.0 feet where there is the change of section/re-entrant corner on the upstream face, and similarly, at the row of elements above Elevation 1237.14 feet, at the upper portion of the dam where there is another change of section and re-entrant corner.

Figure 20 shows the vertical stress histories of the five further upstream elements, numbers 297, 298, 299, 300, and 301. When examining the behavior of element number 297 (the top graph), at the heel of the dam, it is shown that initially the element is in a state of compression at the start of the earthquake. As time marches on, and the structure begins to respond to the ground motion, the vertical stresses in element 297 start to cycle between compressive and tensile, with the maximum vertical tensile stress of 1136 lb/in^2 occurring at 13.36 seconds into the earthquake. Surely, the magnitude of this stress would likely cause cracking of the concrete at the heel, however, upon closer examination of the record one can observe that the maximum stress is only a spike in the total record and that there are only two such spikes exceeding the value of 750 lb/in^2 tension. Proceeding with the examination of the stresses within the rest of the elements along the base, one can observe that the magnitudes of the vertical stresses decrease with an increase of distance downstream of the heel, to the point where elements 300 and 301 contain no vertical tensile stresses at all. Figure 21 is a continuation of the vertical stresses at the base of the dam showing stress histories in elements 302, 303, and 304. Element 302 continues the pattern of experiencing compressive stresses during the earthquake, but moving towards the elements at the toe, tensile stresses increase as the dam is being rocked back and forth (in two dimensions) and the maximum vertical tensile stress in element 304, at the toe, is 367 lb/in^2.

Figure 21 also includes the far upstream and downstream element of the second row of elements. The upstream element, 289, cycles between compression and tension during its major response to the ground motion. A vertical tensile stress of 1141 lb/in^2 tension is the maximum, but again is a spike , and although it may cause cracking of the concrete, the stress history indicates the tensile stresses drop off quickly, moving into the center portion of the model.

The next row of elements to be investigated are the elements just below elevation 720.0 feet at the change of section on the upstream face. The three upstream and two downstream element vertical stress histories are shown in Figure 22. Stresses in element 281 (upstream) cycle through compressive and tensile, with the highest vertical tensile stress being 1478 lb/in^2. Moving into the central portion of the model, stresses diminish quickly, and again rise slightly as approaching the downstream face. Figure 23 shows elements just above the change of section at elevation 720.0 feet, and as would be expected, vertical tensile stresses are some of the highest experienced throughout the entire model. The maximum vertical tensile stress in the upstream element (273) is 1660 lb/in^2, with five excursions above 750 lb/in^2 occurring during the earthquake. This stress reduces, as in the rows of elements below, moving away from the upstream face and increases again slightly approaching the downstream face. It should be noted that although the 1660 lb/in^2 may appear to be excessive, this stress is from the worst case loading scenario. The magnitude of these stresses would be reduced with a more refined analysis including hydrodynamic interaction using compressible fluids, radiational damping, mass included in the foundation, and allowing arch action to develop by using a three dimensional model.

Finally, the row of elements above the change of section/re-entrant corner near the top of the dam on the downstream face at elevation 1237.1 feet is investigated. Figures 24 and 25 show the vertical stress histories of these elements plus the two downstream elements in the row above. As would be expected, the upstream and downstream elements cycle through compressive and tensile stresses, with the maximum vertical tensile stress of 657 lb/in^2 occurring in the downstream element number 80 (at the change of section) at the time of 7.00 seconds.

The model of the proposed enlargement to Shasta Dam was also checked for sliding stability at the base of the dam, just above the change of section on the upstream face at elevation 720.0, and just above the change of section on the downstream face at elevation 1237.1. Figure 26 shows graphical time history output for the sliding factors of safety for the row of elements at the base of the dam in contact with the foundation. As can be seen, that using the assumed value of cohesion, the factor of safety against sliding begins at a value above 3.0 at the start of the earthquake, cycles about this value, mostly on the high side, and returns to this value at the end of the record. The minimum factor of safety of 1.32 occurs at 13.34 seconds into the earthquake. The second graph shows that during the shaking the base remains bonded to the foundation until just past 6.00 seconds into the record, where then only 87.5 percent remains bonded (7 of 8 elements), continuing to about 13 seconds where, again, some bond is lost and continues through the end of the record with 62.5 percent of the base intact (bonded 5 of 8 elements).

Figure 27 shows the same graphical output for the row of elements just above the change of section at elevation 720.0 feet, and Figure 28 for that row of elements above the change of section at elevation 1237.1 feet.

2.5.6 Analysis - Dynamic -Stresses - 300-Foot High RCC Wing Dam

The 300-foot high RCC wing dam model was subjected to the same ground motion time history as was the enlargement mode, and damping was again assumed to be five percent of critical. Because this model showed dramatic stability in the initial GRAVDAM analysis, only the lower rows of elements were investigated for stress histories. Figure 29 shows the vertical stress histories for elements 153 through 157. Element number 153, at the heel of the dam, experiences the highest vertical tensile stress during the earthquake. Beginning in the compressive stress area, the vertical stresses in the element start cycling between compression and tension, peaking at 850 lb/in^2 tension at 7.36 seconds, and then diminishing into the compressive area for the remainder of the record. The adjacent downstream element, 154, experiences only a fraction of the vertical tensile stress its neighbor has, and tensile stresses quickly diminish while moving towards the center of the dam. Figure 30 picks up with element 158 and vertical tensile stresses begin to rise moving towards the extreme downstream element 160, where the maximum vertical tensile stress is 265 lb/in^2. Figure 30 also shows the stress histories of the two downstream elements in the second row above the foundation, elements 151 and 152, respectively.

Figure 31 shows the vertical stress time histories for the bottom five upstream elements, and Figure 32 the bottom five downstream elements. It is interesting to note that maximum response in the upstream elements occur at time 7.50 seconds, and that maximum response in the downstream elements at 7.36 seconds (except element 160 at 7.34 seconds).

Figure(s) 33a-b show the state of stress within the lower portion of the dam at time 7.36 seconds. At this time step, vertical tensile stresses exist in all of the downstream elements, increasing in height above the foundation contact to a maximum of 333 lb/in^2, and then decreasing in magnitude, while at the same time vertical compressive stresses in the upstream elements decrease in magnitude with increasing height above the foundation contact. This condition suggests that the structure is deflecting upstream into the reservoir at this time in response to the ground motions. At time 7.50 seconds (Figure 34), the cycle has reversed and the upstream elements are in a state of high vertical tensile stress, decreasing in magnitude with an increase in height, and the downstream elements are in a state of vertical compressive stress.

Figure 35 shows the graphical time history output for the sliding factors of safety. Conservative values were assumed for the shear strength properties in the RCC of no tensile strength and no cohesion when the bond is broken. Even with these properties, the sliding factor of safety only dropped below 1.0 once during the earthquake.

3.5 Results

The evaluation of results of static and dynamic analyses of the proposed enlargement of Shasta Dam indicate, at this preliminary level of study, that the structure raised to elevation 1280.0 feet, with a 0.70:1 downstream slope can safely resist the forces exerted by the normal loading combination of gravity and reservoir water surface at 1280.0 feet, and also the superimposed dynamic loading of the MCE. Based on the material properties assumed for these analyses, some localized cracking of the concrete may be expected on the upstream face above the foundation contact, and on the upstream face above the change of section at elevation 720.0 feet during MCE loading, however, stress histories indicate that the duration of maximum tensile stresses to initiate these cracks is immediate and damped quickly; redistribution of stresses would also alleviate high stresses in adjacent elements.

The results of the analyses of the 300-foot high RCC wing dam section indicate that this proposed design can very safely resist the forces of the combined loading condition of gravity and reservoir water surface at elevation 1280.0 feet. Under the superimposed loading of the MCE, vertical tensile stresses in excess of what may be the tensile strength of the RCC would likely cause cracking of the material on the upstream face in the lower portion of the dam, and to a lesser degree, on the lower portion of the downstream face. These tensions can be controlled in final design by placing stronger mass concrete in these areas. No loss of structural integrity is expected in either case.

4.0 Conclusions

The conclusions based herein are based on extremely conservative assumptions, namely, assumed material properties of both the mass concrete, RCC, and foundation rock, Westergaard's added mass, ground motions associated with the recommended MCE, and the 2-dimensional, linear elastic finite element analyses that did not include the effects of flexible foundation rock, compressible water, or the stability producing effects of arch action in a three dimensional model. Including these effects would improve calculated stability.

A. The proposed enlargement of Shasta Dam to elevation 1280.0, with a 0.70:1 slope on the downstream face is stressed to a level well within Reclamation criteria under the usual loading combination of gravity and reservoir water surface elevation at 1280.0 feet, using the assumed material properties.

B. The proposed enlargement of Shasta Dam to elevation 1280.0, with a 0.70:1 slope on the downstream face is stressed to controllable levels in final design under the extreme loading combination of gravity and reservoir water surface at 1280.0 feet, plus loading due to the MCE using the assumed material properties.

C. The proposed 300-foot high RCC wing dam(s) associated with the enlargement of the existing Shasta Dam is stressed to a level well within Reclamation criteria under the usual loading combination of gravity and reservoir water surface elevation at 1280.0 feet.

D. The proposed 300-foot high RCC wing dam(s) associated with the enlargement of the existing Shasta Dam, under the extreme loading combination of gravity, reservoir water surface elevation at 1280.0 feet, plus effects of the MCE would show localized horizontal cracking (disbonding) of the RCC material on both the upstream and downstream faces of the dam, only due to the nature of RCC material and construction methods used to place it. No loss of structural integrity is expected due to cracking which may occur during seismic events.

References

[1} Memorandum to Head, Concrete Dams Section, through Supervisor, Analytical Design Unit. Subject: Appraisal Designs for Several Increases in Height of Shasta Dam - Central Valley Project - California. Bureau of Reclamation, Denver, Colorado, July 8, 1978.

[2] Westergaard, H. M., "Water Pressures on Dams During Earthquakes," Transactions, ASCE, Vol. 98, Paper No. 1835, 1933.

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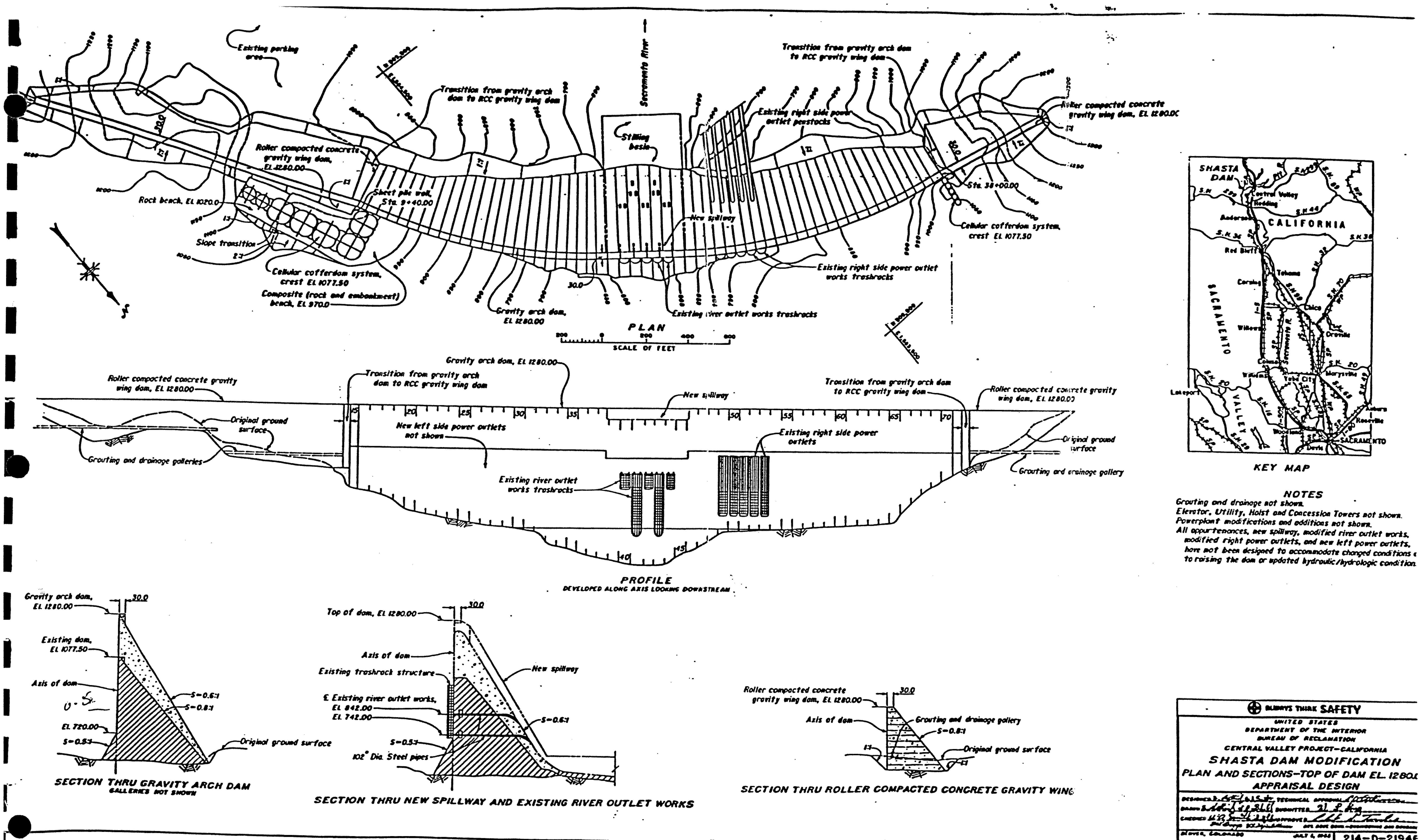
[4] Bathe, K-J., Wilson, E.L., Peterson, F.E., "SAP-IV, A Structural Analysis Program for the Static and Dynamic Analysis of Linear Systems," Report No. EERC 73-11, Berkeley, California, June 1973 - Revised April 1974.

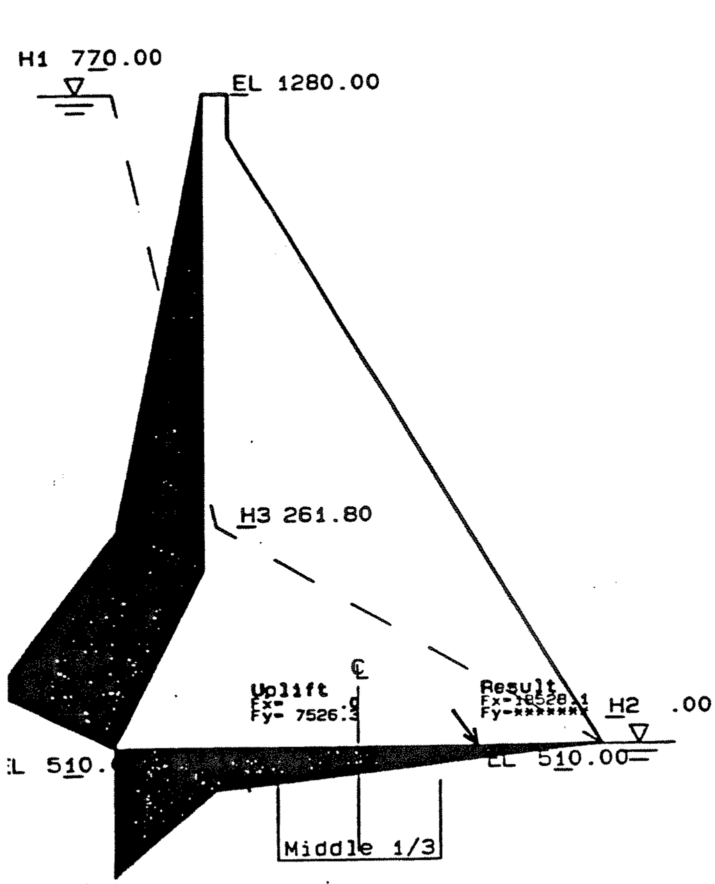
[5] Vetter, U., "Risk Assessment for Spring Creek Debris Dam, Earthquake Loading Parameters, Central Valley Project, California," Technical Memorandum No. D8330-96-19, Bureau of Reclamation, Denver, Colorado, October 9, 1996.

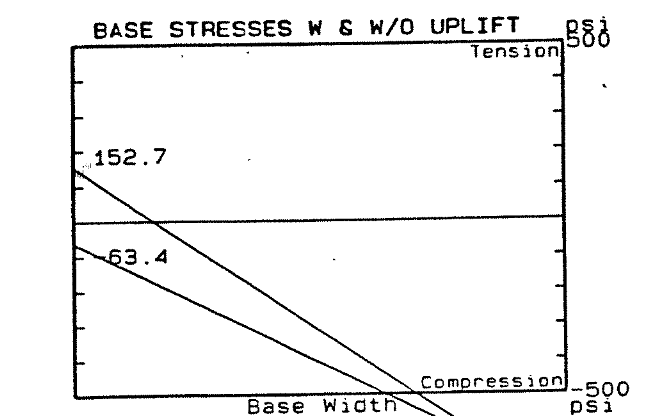
List of Figures

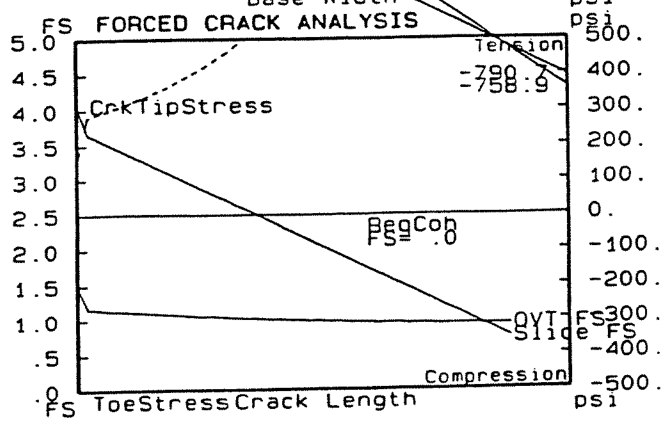


Existing parking area
Sacramento River
Transition from gravity arch dam to RCC gravity wing dam
Stilling basin
Existing right side power outlet penstocks
Roller compacted concrete gravity wing dam, EL 1280.00
Rock beach, EL 1020.0
Sheet pile wall, Sta. 9+40.00
Slope transition
Cellular cofferdom system, crest EL 1077.50
Composite (rock and embankment) beach, EL 970.0
New spillway
Sta. 38+00.00
Existing right side power outlet works trashracks
Gravity arch dam, EL 1280.00
Existing river outlet works trashracks
PLAN
SCALE OF FEET
Original ground surface
Grouting and drainage galleries
New left side power outlets not shown
Existing right side power outlets
Grouting and drainage gallery
PROFILE
DEVELOPED ALONG AXIS LOOKING DOWNSTREAM
Existing dam, EL 1077.50
Axis of dam
EL 720.00
SECTION THRU GRAVITY ARCH DAM
GALLERIES NOT SHOWN
Top of dam, EL 1280.00
Existing trashrack structure
℄ Existing river outlet works, EL 842.00, EL 742.00
102" Dia. Steel pipes
SECTION THRU NEW SPILLWAY AND EXISTING RIVER OUTLET WORKS
SECTION THRU ROLLER COMPACTED CONCRETE GRAVITY WING
SHASTA DAM
CALIFORNIA
SACRAMENTO
VALLEY
KEY MAP
NOTES
Grouting and drainage not shown.
Elevator, Utility, Hoist and Concession Towers not shown.
Powerplant modifications and additions not shown.
All appurtenances, new spillway, modified river outlet works, modified right power outlets, and new left power outlets, have not been designed to accommodate changed conditions due to raising the dam or updated hydraulic/hydrologic condition.
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT—CALIFORNIA
SHASTA DAM MODIFICATION
PLAN AND SECTIONS—TOP OF DAM EL. 1280.
APPRAISAL DESIGN
DENVER, COLORADO
214-D-21946

Figure 1








```
DAM DIMENSIONS AND CRITERIA
 Analysis type                  Standard
 Criteria at drains             USBR
 nheel 1     .0  510.0  ntoe 6  567.0   510.0
 nus   3  105.0 1280.0  nds  4  135.0  1280.0
 Top of dam elevation            1280.000
 Base of dam elevation            510.000
 Thickness of crest                30.000
 Base width                       567.000
 Reservoir elevation             1280.000
 Tailwater elevation              510.000
 Silt elevation                   510.000
 Initial crack length                .000
 Drain distance from axis          15.000
 Drain distance from heel         120.000
 Drain efficiency                    .660
 Drainage gallery elevation       510.000
 Head at H1, Heel                 770.0000
 Head at H2, Toe                     .0000
 Head at H3, Drain                261.8000
 Head at H4, Gallery                 .0000
 USBR  H3=H2+(H1-H2)*(1-E)

MATERIAL PROPERTIES:
 Density of concrete            .15400 K/ft3
            water               .06250 K/ft3
            horiz sat silt       .085 K/ft3
            vert  sat silt       .120 K/ft3
 Cohesion:   Break bond       600.000 lb/in2
             Apparent            .000 lb/in2
 Friction:        Bonded        1.000    45.0 deg
   (tangent&angle) Unbonded     1.000    45.0 deg
 Fraction of area bonded        1.000

FORCES, POINT OF APPLICATION, AND MOMEMTS
 (Moments about uncracked base at     283.5    510.0)
Desc  ForceX  ForceY      CGX      CGY MomentX MomentY
Dam       .0-29205.3    247.5    757.8       .0*******
Res  18528.1 -4364.1     49.7    766.7***************
Uplt      .0  7526.3    156.5    510.0      .0955919.1
Rslt 18528.1-26043.1    423.2    510.0********      .0

RESULTANT FORCE                         w/uplift    w/o uplift
Horizontal component (+=d/s)           18528.13   18528.13 K
Vertical   component (+=up )          -26043.12  -33569.39 K
Resultant force                        31961.47   38343.13 K
Distance from CL to resultant            139.75      79.94
                 to 1/3 base              94.50
                 to 1/2 base             141.75
Moment at 283.50 from heel  3639412.962683493.86 k-ft
   OVERTURNING SF =                        1.48

VERTICAL STRESSES AT HEEL AND TOE (Tension is positive)
Area of base, A                             567.00 ft2
Moment of inertia, I                    ********** ft4
Moment arm, c                               283.50 ft
Stress                         w/uplift    w/o uplift
Axial stress, P/A               -318.97     -411.15 lb/in2
Moment stress, Mc/I              471.69      347.79 lb/in2
Vertical stress at heel          152.72      -63.35 lb/in2
Vertical stress at toe          -790.66     -758.94 lb/in2

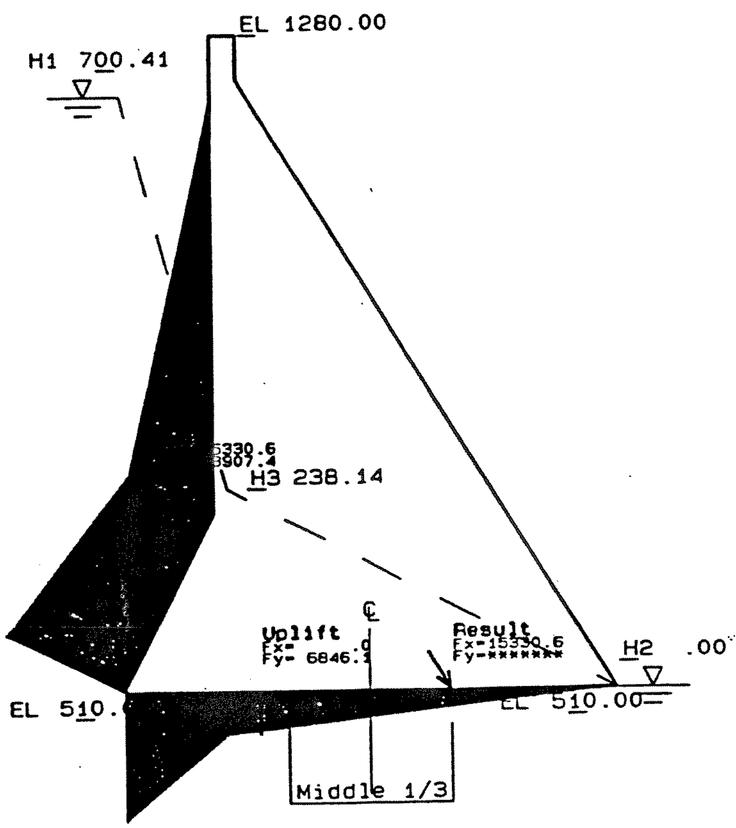
RECLAMATION CRACKING CRITERIA (szu = pwh - ft/s)
Drain factor (p)=   .647, Safety factor(s)=    .00
    Tension(ft)        szu          Crack
       psi             psi        Prediction
       .00NaN                     No crk
     25.00             .00        No crk
     75.00             .00        No crk
    125.00             .00        No crk
    175.00             .00        No crk
    225.00             .00        No crk

SLIDING FACTORS OF SAFETY
Total horizontal forces (driving)    18528.13 kips
Total vertical forces               -26043.12 kips
Safety Factor for above strengths        4.05
Cohesion(Bonded)=    .00 psi req for FS=   .0
Sliding safety factors for various cohesions:
BreakBond-psi      .0    50.0   100.0   150.0   200.0   250.0
Resisting-K  26043.130125.534207.938290.342372.746455.1
Safety factor   1.41    1.63    1.85    2.07    2.29    2.51
Required strengths to get these safety factors while
  other given values constant   SF=    1.0      2.0      3.0
    Bonded area:      cohesion (psi)    .0    134.9    361.8
               friction angle (deg)     .0       .0     14.2

FORCED CRACK RESULTS
Heel initially in tension
Crack extends entire width of base
```

Figure 2

C.C.I CRACKINIT USBR




```
DAM DIMENSIONS AND CRITERIA
 Analysis type                          CrackInit
 Criteria at drains                     USBR
 nheel 1       .0  510.0  ntoe 6  567.0  510.0
 nus    3  105.0 1280.0  nds  4  135.0 1280.0
 Top of dam elevation                  1280.000
 Base of dam elevation                  510.000
 Thickness of crest                      30.000
 Base width                             567.000
 Reservoir elevation                   1210.412
 Tailwater elevation                    510.000
 Silt elevation                         510.000
 Initial crack length                      .000
 Drain distance from axis                15.000
 Drain distance from heel               120.000
 Drain efficiency                          .660
 Drainage gallery elevation             510.000
 Head at H1, Heel                      700.4123
 Head at H2, Toe                          .0000
 Head at H3, Drain                     238.1402
 Head at H4, Gallery                      .0000
 USBR  H3=H2+(H1-H2)*(1-E)

MATERIAL PROPERTIES:
 Density of concrete                  .15400 K/ft3
              water                   .06250 K/ft3
              horiz sat silt            .085 K/ft3
              vert  sat silt            .120 K/ft3
 Cohesion:      Break bond           600.000 lb/in2
                Apparent                .000 lb/in2
 Friction:            Bonded           1.000    45.0 deg
   (tangent&angle)  Unbonded           1.000    45.0 deg
 Fraction of area bonded               1.000

FORCES, POINT OF APPLICATION, AND MOMEMTS
(Moments about uncracked base at     283.5    510.0)
Desc   ForceX  ForceY       CGX      CGY MomentX MomentY
Dam        .0-29205.3     247.5    757.8       .0********
Res   15330.5 -3907.4      49.4    743.5*****************
Uplt       .0  6846.1     156.5    510.0       .0869529.3
Rslt  15330.5-26266.6     378.0    510.0********       .0

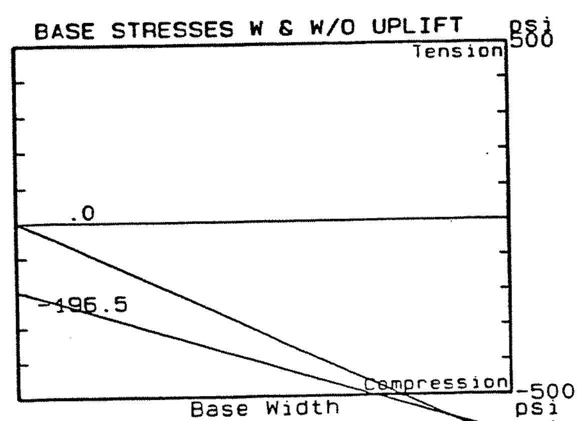
RESULTANT FORCE                        w/uplift    w/o uplift
Horizontal component  (+=d/s)          15330.55    15330.55 K
Vertical   component  (+=up )         -26266.63   -33112.72 K
Resultant force                        30413.18    36489.42 K
Distance from CL to resultant             94.50       48.70
                 to 1/3 base              94.50
                 to 1/2 base             141.75
Moment at 283.50 from heel   2482195.951612666.67 k-ft
   OVERTURNING SF =                        1.78

VERTICAL STRESSES AT HEEL AND TOE (Tension is positiv
Area of base, A                              567.00 ft2
Moment of inertia, I                     ********** ft4
Moment arm, c                                283.50 ft
Stress                          w/uplift     w/o uplift
Axial stress, P/A                -321.71     -405.55 lb/in2
Moment stress, Mc/I               321.71      209.01 lb/in2
Vertical stress at heel              .00     -196.54 lb/in2
Vertical stress at toe           -643.41     -614.56 lb/in2

RECLAMATION CRACKING CRITERIA (szu = pwh - ft/s)
Drain factor (p)=   .647,  Safety factor(s)=    .00
     Tension(ft)       szu        Crack
        psi            psi       Prediction
           .00NaN                No crk
         25.00         .00       No crk
         75.00         .00       No crk
        125.00         .00       No crk
        175.00         .00       No crk
        225.00         .00       No crk

SLIDING FACTORS OF SAFETY
Total horizontal forces (driving)     15330.55 kips
Total vertical forces                -26266.63 kips
Safety Factor for above strengths         4.91
Cohesion(Bonded)=    .00 psi req for FS=   .0
Sliding safety factors for various cohesions:
BreakBond-psi       .0    50.0   100.0   150.0   200.0  250
Resisting-K  26266.630349.034431.438513.842596.246678
Safety factor    1.71    1.98    2.25    2.51    2.78    3.
Required strengths to get these safety factors while
  other given values constant  SF=     1.0     2.0     3
    Bonded area:    cohesion (psi)      .0    53.8   241
                friction angle (deg)    .0      .0

FORCED CRACK RESULTS
Initially compression at heel
Any crack >    .00ft from heel grows
Crack stops at  299.73ft from heel
```



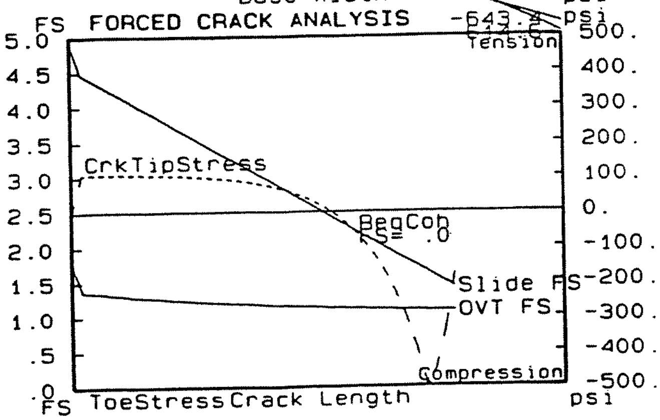


Figure 3

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0.7:1
USBR
STND

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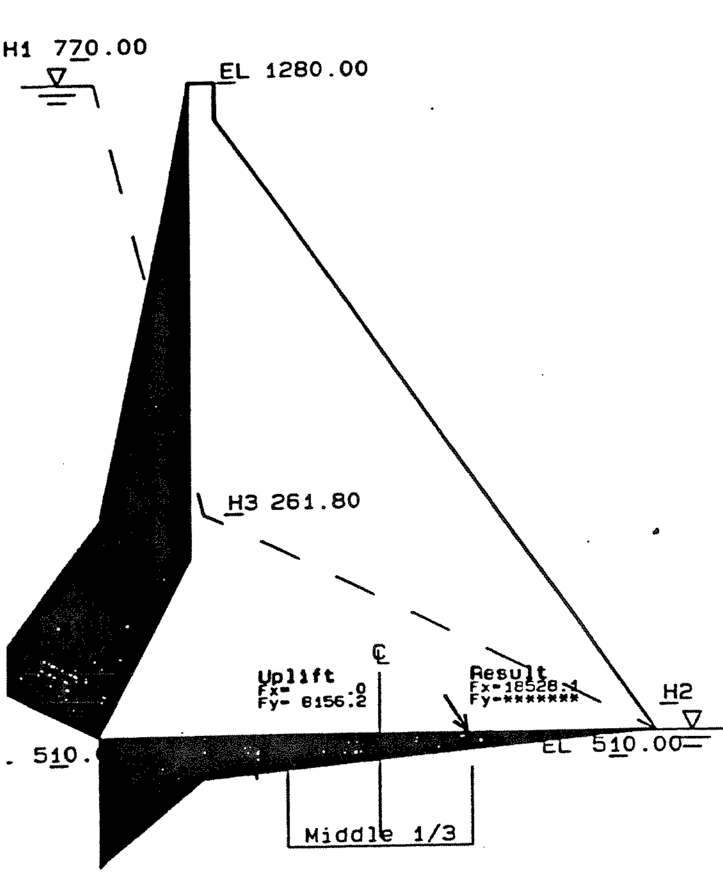


DAM DIMENSIONS AND CRITERIA

Analysis type	Standard	
Criteria at drains	USBR	
nheel 1 .0 510.0	ntoe 6 644.0 510.0	
nus 3 105.0 1280.0	nds 4 135.0 1280.0	
Top of dam elevation	1280.000	
Base of dam elevation	510.000	
Thickness of crest	30.000	
Base width	644.000	
Reservoir elevation	1280.000	
Tailwater elevation	510.000	
Silt elevation	510.000	
Initial crack length	.000	
Drain distance from axis	15.000	
Drain distance from heel	120.000	
Drain efficiency	.660	
Drainage gallery elevation	510.000	
Head at H1, Heel	770.0000	
Head at H2, Toe	.0000	
Head at H3, Drain	261.8000	
Head at H4, Gallery	.0000	

USBR H3=H2+(H1-H2)*(1-E)

MATERIAL PROPERTIES:

Density of concrete	.15400 K/ft3		
water	.06250 K/ft3		
horiz sat silt	.085 K/ft3		
vert sat silt	.120 K/ft3		
Cohesion: Break bond	600.000 lb/in2		
Apparent	.000 lb/in2		
Friction: Bonded	1.000	45.0 deg	
(tangent&angle) Unbonded	1.000	45.0 deg	
Fraction of area bonded	1.000		

FORCES, POINT OF APPLICATION, AND MOMEMTS
(Moments about uncracked base at 322.0 510.0)

Desc	ForceX	ForceY	CGX	CGY	MomentX	MomentY
Dam	.0	-33754.4	273.4	758.7	.0	********
Res	18528.1	-4364.1	49.7	766.7	********	********
Uplt	.0	8156.2	178.7	510.0	.0	********
Rslt	18528.1	-29962.3	425.3	510.0	********	.0

RESULTANT FORCE	w/uplift	w/o uplift
Horizontal component (+=d/s)	18528.13	18528.13 K
Vertical component (+=up)	-29962.28	-38118.50 K
Resultant force	35228.25	42382.92 K
Distance from CL to resultant	103.33	50.55
to 1/3 base	107.33	
to 1/2 base	161.00	
Moment at 322.00 from heel	3095975.50	1926939.73 k-ft
OVERTURNING SF =	1.77	

VERTICAL STRESSES AT HEEL AND TOE (Tension is positive)

Area of base, A	644.00 ft2	
Moment of inertia, I	********** ft4	
Moment arm, c	322.00 ft	
Stress	w/uplift	w/o uplift
Axial stress, P/A	-323.09	-411.04 lb/in2
Moment stress, Mc/I	311.04	193.59 lb/in2
Vertical stress at heel	-12.05	-217.45 lb/in2
Vertical stress at toe	-634.13	-604.63 lb/in2

RECLAMATION CRACKING CRITERIA (szu = pwh - ft/s)
Drain factor (p)= .615, Safety factor(s)= .00

Tension(ft) psi	szu psi	Crack Prediction
.00	NaN	No crk
25.00	.00	No crk
75.00	.00	No crk
125.00	.00	No crk
175.00	.00	No crk
225.00	.00	No crk

SLIDING FACTORS OF SAFETY

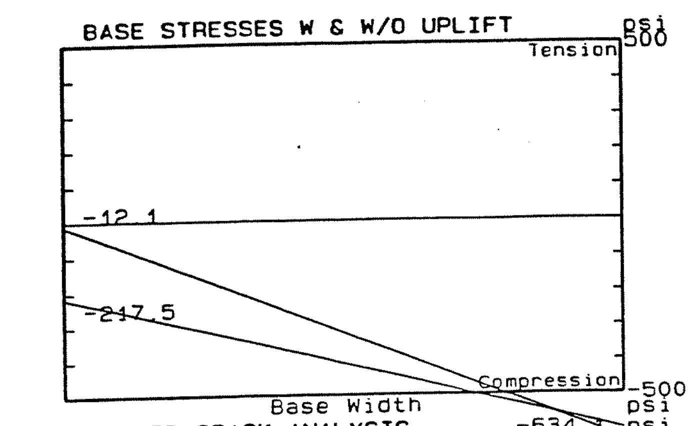
Total horizontal forces (driving) 18528.13 kips
Total vertical forces -29962.28 kips
Safety Factor for above strengths 4.62
Cohesion (Bonded) = .00 psi req for FS= .0

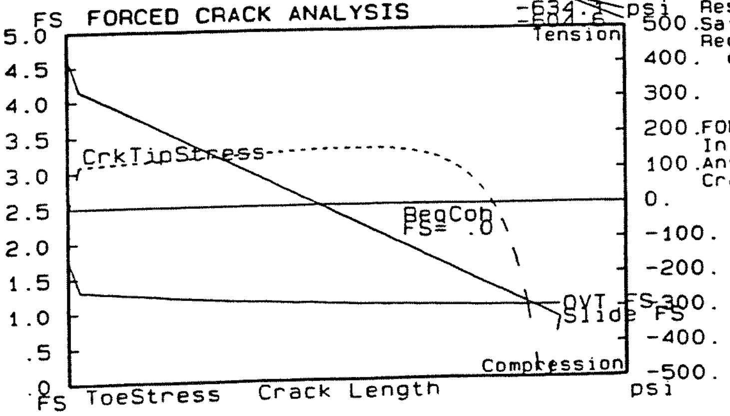
Sliding safety factors for various cohesions:

BreakBond-psi	.0	50.0	100.0	150.0	200.0	250.0
Resisting-K	29962.3	34599.1	39235.9	43872.7	48509.5	53146.3
Safety factor	1.62	1.87	2.12	2.37	2.62	2.87

Required strengths to get these safety factors while

other given values constant SF=	1.0	2.0	3.0
Bonded area: cohesion (psi)	.0	76.5	276.3
friction angle (deg)	.0	.0	.0





FORCED CRACK RESULTS
Initially compression at heel
Any crack > 1.19ft from heel grows
Crack stops at 489.19ft from heel

Figure 4

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C.7.1) L.P.K. CRACK INIT

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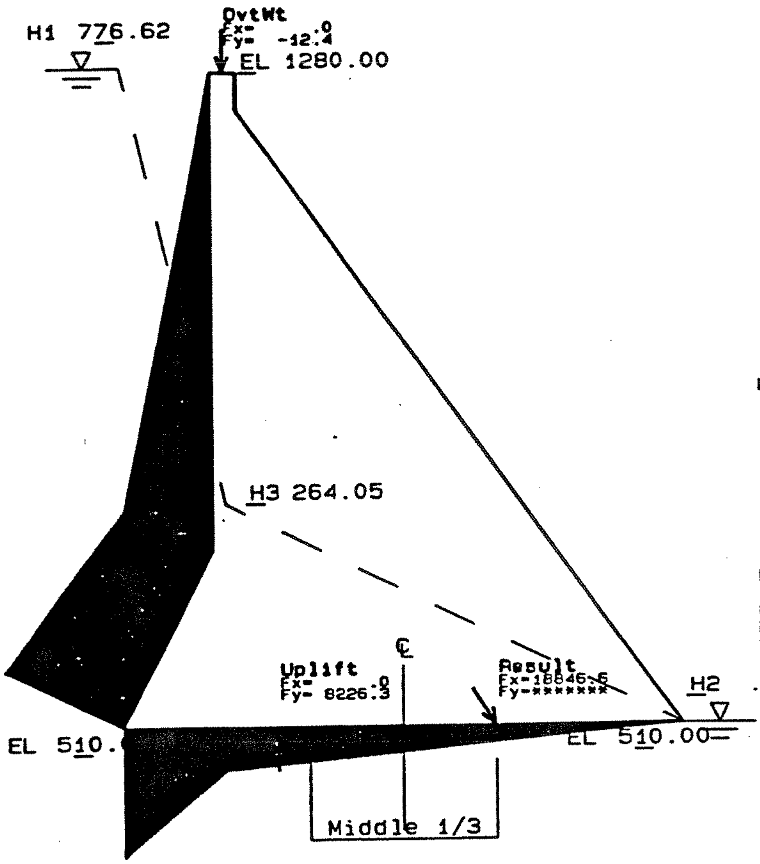

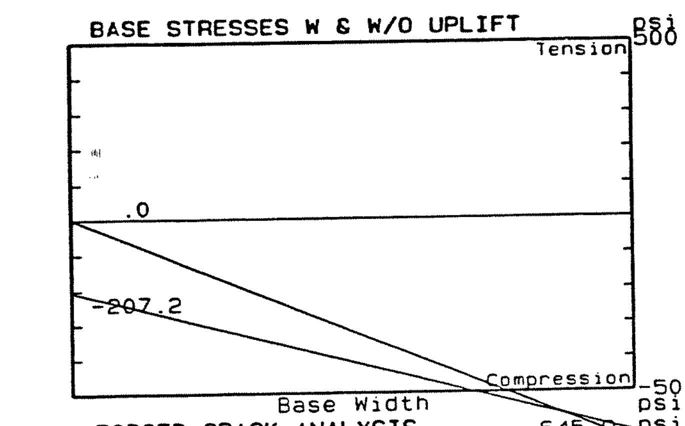

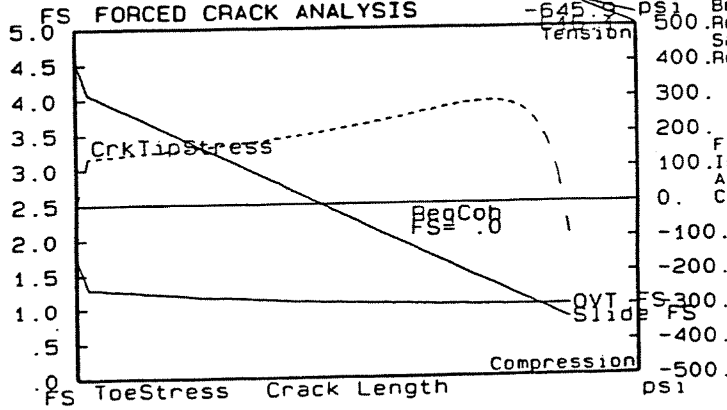


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DAM DIMENSIONS AND CRITERIA
 Analysis type                      CrackInit
 Criteria at drains                 USBR
 nheel 1      .0  510.0  ntoe 6   644.0  510.0
 nus   3  105.0 1280.0   nds  4   135.0 1280.0
 Top of dam elevation            1280.000
 Base of dam elevation            510.000
 Thickness of crest                30.000
 Base width                       644.000
 Reservoir elevation             1286.617
 Tailwater elevation              510.000
 Silt elevation                   510.000
 Initial crack length                .000
 Drain distance from axis          15.000
 Drain distance from heel         120.000
 Drain efficiency                    .660
 Drainage gallery elevation       510.000
 Head at H1, Heel                 776.6172
 Head at H2, Toe                     .0000
 Head at H3, Drain                264.0498
 Head at H4, Gallery                 .0000
 USBR  H3=H2+(H1-H2)*(1-E)

MATERIAL PROPERTIES:
 Density of concrete              .15400 K/ft3
            water                 .06250 K/ft3
            horiz sat silt          .085 K/ft3
            vert  sat silt          .120 K/ft3
 Cohesion:   Break bond          600.000 lb/in2
             Apparent               .000 lb/in2
 Friction:          Bonded         1.000    45.0 deg
  (tangent&angle)   Unbonded       1.000    45.0 deg
 Fraction of area bonded           1.000

FORCES, POINT OF APPLICATION, AND MOMEMTS
(Moments about uncracked base at     322.0    510.0)
Desc   ForceX   ForceY      CGX      CGY MomentX MomentY
Dam        .0-33754.4     273.4    758.7      .0*******
Res   18846.6  -4407.5     49.8    768.8**************
Uplt       .0   8226.3    178.7    510.0      .0*******
OvtW       .0    -12.4    120.0   1280.0      .0 -2506.3
Rslt  18846.6-29948.0     429.3    510.0*******       .0

RESULTANT FORCE                       w/uplift   w/o uplift
Horizontal component  (+=d/s)         18846.58   18846.58 K
Vertical   component  (+=up )        -29948.02  -38174.33 K
Resultant force                       35384.70   42573.15 K
Distance from CL to resultant           107.33      53.32
                 to 1/3 base            107.33
                 to 1/2 base            161.00
Moment at 322.00 from heel   3214416.342035334.19 k-ft
   OVERTURNING SF =                       1.74

VERTICAL STRESSES AT HEEL AND TOE (Tension is positive
Area of base, A                              644.00 ft2
Moment of inertia, I                     ********** ft4
Moment arm, c                                322.00 ft
Stress                          w/uplift    w/o uplift
Axial stress, P/A                -322.94     -411.65 lb/in2
Moment stress, Mc/I               322.94      204.48 lb/in2
Vertical stress at heel              .00     -207.16 lb/in2
Vertical stress at toe           -645.88     -616.13 lb/in2

RECLAMATION CRACKING CRITERIA (szu = pwh - ft/s)
Drain factor (p)=   .615,  Safety factor(s)=    .00
    Tension(ft)        szu       Crack
      psi              psi       Prediction
         .00NaN                  No crk
       25.00           .00       No crk
       75.00           .00       No crk
      125.00           .00       No crk
      175.00           .00       No crk
      225.00           .00       No crk

SLIDING FACTORS OF SAFETY
Total horizontal forces (driving)     18846.58 kips
Total vertical forces                -29948.02 kips
Safety Factor for above strengths         4.54
Cohesion(Bonded)=    .00 psi req for FS=   .0
Sliding safety factors for various cohesions:
BreakBond-psi      .0    50.0   100.0   150.0   200.0   250
Resisting-K  29948.034584.839221.643858.448495.253132.
Safety factor    1.59    1.84    2.08    2.33    2.57    2.
Required strengths to get these safety factors while
   other given values constant  SF=    1.0      2.0     3
     Bonded area:     cohesion (psi)      .0     83.5   286
                friction angle (deg)      .0       .0     1

FORCED CRACK RESULTS
Initially compression at heel
Any crack >     .00ft from heel grows
Crack stops at  559.96ft from heel
```

Figure 5

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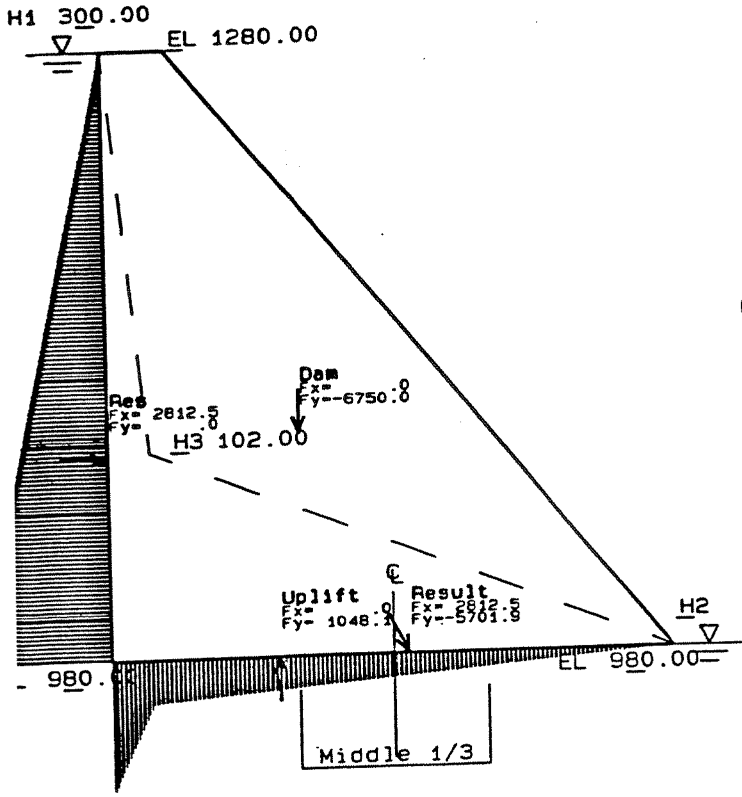


DAM DIMENSIONS AND CRITERIA

Analysis type			Standard
Criteria at drains			USBR
nheel 1 .0 980.0	ntoe 4	270.0	980.0
nus 2 .0 1280.0	nds 3	30.0	1280.0
Top of dam elevation		1280.000	
Base of dam elevation		980.000	
Thickness of crest		30.000	
Base width		270.000	
Reservoir elevation		1280.000	
Tailwater elevation		980.000	
Silt elevation		980.000	
Initial crack length		.000	
Drain distance from axis		20.000	
Drain distance from heel		20.000	
Drain efficiency		.660	
Drainage gallery elevation		980.000	
Head at H1, Heel		300.0000	
Head at H2, Toe		.0000	
Head at H3, Drain		102.0000	
Head at H4, Gallery		.0000	

USBR H3=H2+(H1-H2)*(1-E)

MATERIAL PROPERTIES:

Density of concrete	.15000 K/ft3		
water	.06250 K/ft3		
horiz sat silt	.085 K/ft3		
vert sat silt	.120 K/ft3		
Cohesion: Break bond	300.000 lb/in2		
Apparent	.000 lb/in2		
Friction: Bonded	1.000	45.0 deg	
(tangent&angle) Unbonded	1.000	45.0 deg	
Fraction of area bonded	1.000		

FORCES, POINT OF APPLICATION, AND MOMEMTS
(Moments about uncracked base at 135.0 980.0)

Desc	ForceX	ForceY	CGX	CGY	MomentX	MomentY
Dam	.0	-6750.0	91.0	1090.0	.0	*******
Res	2812.5	.0	.0	1080.0	281250.0	.0
Uplt	.0	1048.1	80.6	980.0	.0	57053.1
Rslt	2812.5	-5701.9	142.2	980.0	41303.1	.0

RESULTANT FORCE

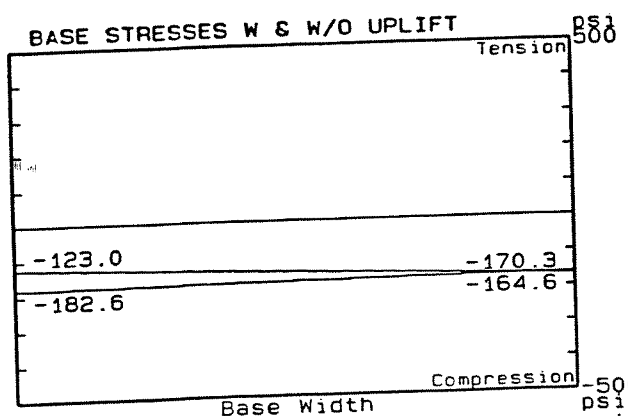
	w/uplift	w/o uplift
Horizontal component (+=d/s)	2812.50	2812.50 K
Vertical component (+=up)	-5701.88	-6750.00 K
Resultant force	6357.79	7312.50 K
Distance from CL to resultant	7.24	-2.33
to 1/3 base	45.00	
to 1/2 base	67.50	
Moment at 135.00 from heel	41303.12	-15749.98 k-ft
OVERTURNING SF =	2.52	

VERTICAL STRESSES AT HEEL AND TOE (Tension is positive)

Area of base, A	270.00 ft2	
Moment of inertia, I	1640250.00 ft4	
Moment arm, c	135.00 ft	
Stress	w/uplift	w/o uplift
Axial stress, P/A	-146.65	-173.61 lb/in2
Moment stress, Mc/I	23.61	-9.00 lb/in2
Vertical stress at heel	-123.05	-182.61 lb/in2
Vertical stress at toe	-170.26	-164.61 lb/in2

RECLAMATION CRACKING CRITERIA (szu = pwh - ft/s)
Drain factor (p) = .457, Safety factor (s) = .00

Tension (ft) psi	szu psi	Crack Prediction
.00NaN		No crk
25.00	.00	No crk
75.00	.00	No crk
125.00	.00	No crk
175.00	.00	No crk
225.00	.00	No crk



SLIDING FACTORS OF SAFETY

Total horizontal forces (driving)	2812.50 kips
Total vertical forces	-5701.88 kips
Safety Factor for above strengths	6.17
Cohesion (Bonded) = .00 psi req for FS=	.0

Sliding safety factors for various cohesions:

BreakBond-psi	.0	50.0	100.0	150.0	200.0	250.0
Resisting-K	5701.9	7645.9	9589.9	11533.9	13477.9	15421.9
Safety factor	2.03	2.72	3.41	4.10	4.79	5.48

Required strengths to get these safety factors while other given values constant

	SF= 1.0	2.0	3.0
Bonded area: cohesion (psi)	.0	.0	70.4
friction angle (deg)	.0	.0	.0

FORCED CRACK RESULTS
Initially compression at heel
No length of crack causes crack growth

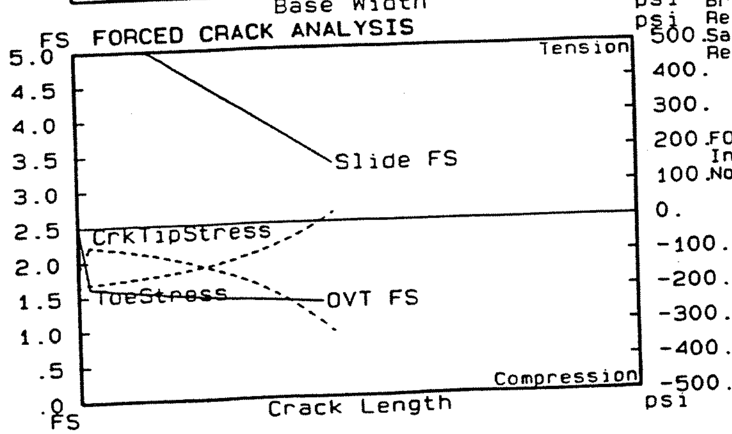
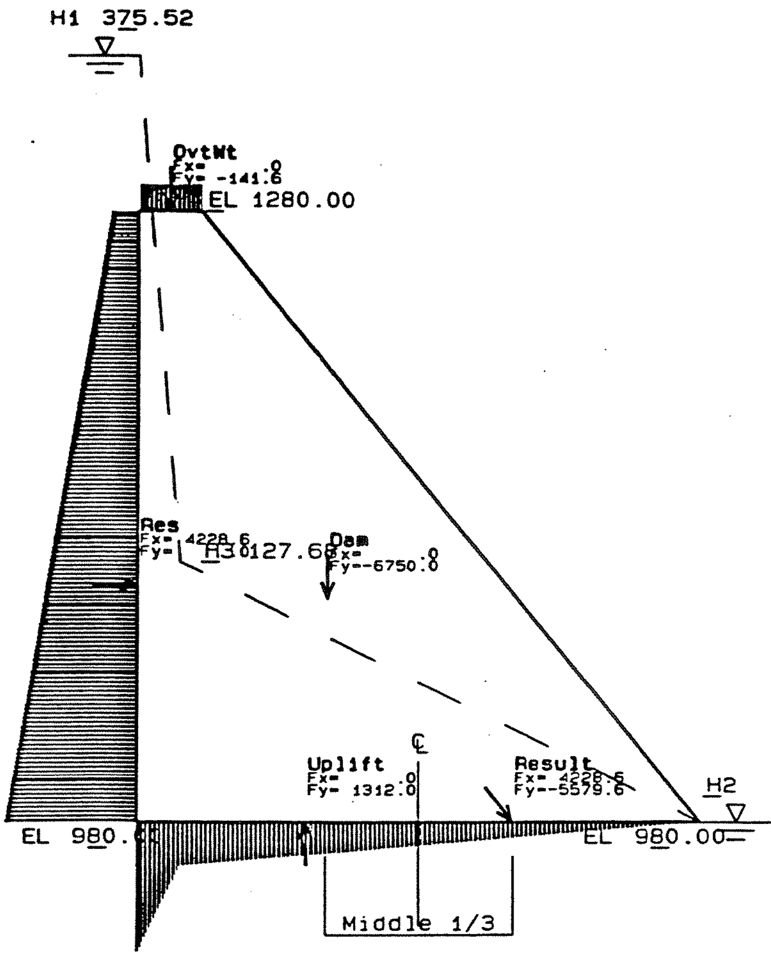


Figure 6

23-Jan-98 05: 57: 59 File=rcc300.gdi




```
DAM DIMENSIONS AND CRITERIA
 Analysis type                    CrackInit
 Criteria at drains               USBR
 nheel 1     .0  980.0  ntoe 4  270.0  980.0
 nus   2     .0 1280.0  nds  3   30.0 1280.0
 Top of dam elevation            1280.000
 Base of dam elevation            980.000
 Thickness of crest                30.000
 Base width                       270.000
 Reservoir elevation             1355.523
 Tailwater elevation              980.000
 Silt elevation                   980.000
 Initial crack length                .000
 Drain distance from axis          20.000
 Drain distance from heel          20.000
 Drain efficiency                    .660
 Drainage gallery elevation       980.000
 Head at H1, Heel                375.5232
 Head at H2, Toe                    .0000
 Head at H3, Drain               127.6779
 Head at H4, Gallery                .0000
 USBR  H3=H2+(H1-H2)*(1-E)

MATERIAL PROPERTIES:
 Density of concrete            .15000 K/ft3
           water                .06250 K/ft3
           horiz sat silt        .085 K/ft3
           vert  sat silt        .120 K/ft3
 Cohesion:   Break bond       300.000 lb/in2
             Apparent            .000 lb/in2
 Friction:         Bonded        1.000    45.0 deg
  (tangent&angle) Unbonded       1.000    45.0 deg
 Fraction of area bonded         1.000

FORCES, POINT OF APPLICATION, AND MOMEMTS
(Moments about uncracked base at    135.0    980.0)
Desc   ForceX  ForceY      CGX     CGY MomentX MomentY
Dam        .0 -6750.0     91.0  1090.0        .0********
Res    4228.6      .0       .0  1096.7493659.1      .0
Uplt       .0  1312.0     80.6   980.0        .0 71415.9
OvtW       .0  -141.6     15.0  1280.0        .0-16992.7
Rslt   4228.6 -5579.6    180.0   980.0251082.3      .0

RESULTANT FORCE                    w/uplift   w/o uplift
Horizontal component (+=d/s)        4228.56    4228.56 K
Vertical   component (+=up )       -5579.62   -6891.61 K
Resultant force                     7000.92    8085.48 K
Distance from CL to resultant         45.00      26.07
                 to 1/3 base          45.00
                 to 1/2 base          67.50
Moment at 135.00 from heel       251082.28 179666.38 k-ft
   OVERTURNING SF =                    1.68

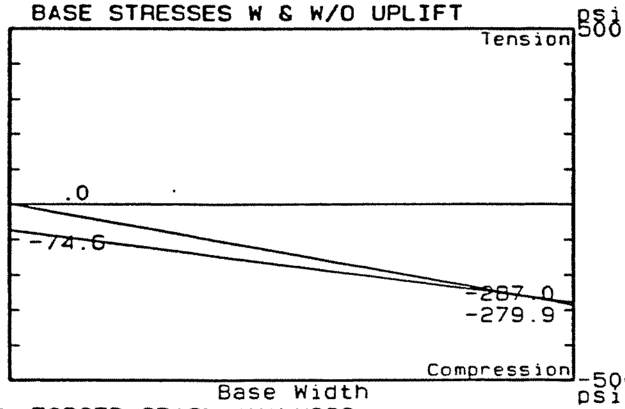
VERTICAL STRESSES AT HEEL AND TOE (Tension is positiv
Area of base, A                            270.00 ft2
Moment of inertia, I                   1640250.00 ft4
Moment arm, c                              135.00 ft
Stress                        w/uplift   w/o uplift
Axial stress, P/A              -143.51    -177.25 lb/in2
Moment stress, Mc/I             143.51     102.69 lb/in2
Vertical stress at heel            .00     -74.56 lb/in2
Vertical stress at toe         -287.02    -279.94 lb/in2

RECLAMATION CRACKING CRITERIA (szu = pwh - ft/s)
Drain factor (p)=  .457, Safety factor(s)=    .00
     Tension(ft)       szu        Crack
       psi             psi        Prediction
         .00NaN                   No crk
        25.00          .00        No crk
        75.00          .00        No crk
       125.00          .00        No crk
       175.00          .00        No crk
       225.00          .00        No crk

SLIDING FACTORS OF SAFETY
Total horizontal forces (driving)     4228.56 kips
Total vertical forces                -5579.62 kips
Safety Factor for above strengths        4.08
Cohesion(Bonded)=    .00 psi req for FS=  .0
Sliding safety factors for various cohesions:
BreakBond-psi       .0   50.0  100.0  150.0  200.0  250
Resisting-K   5579.6 7523.6 9467.611411.613355.615299
Safety factor   1.32   1.78   2.24   2.70   3.16   3.
Required strengths to get these safety factors while
  other given values constant  SF=    1.0    2.0    3
   Bonded area:     cohesion (psi)     .0   74.0  182
               friction angle (deg)    .0     .0   10

FORCED CRACK RESULTS
Initially compression at heel
Any crack >     .00ft from heel grows
```

BASE STRESSES W & W/O UPLIFT



FORCED CRACK ANALYSIS

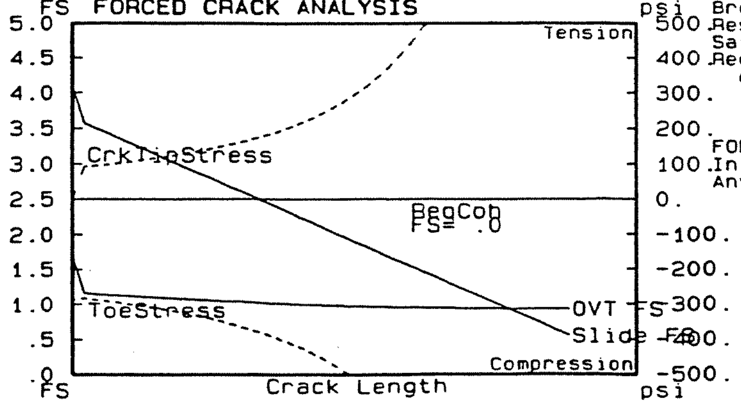
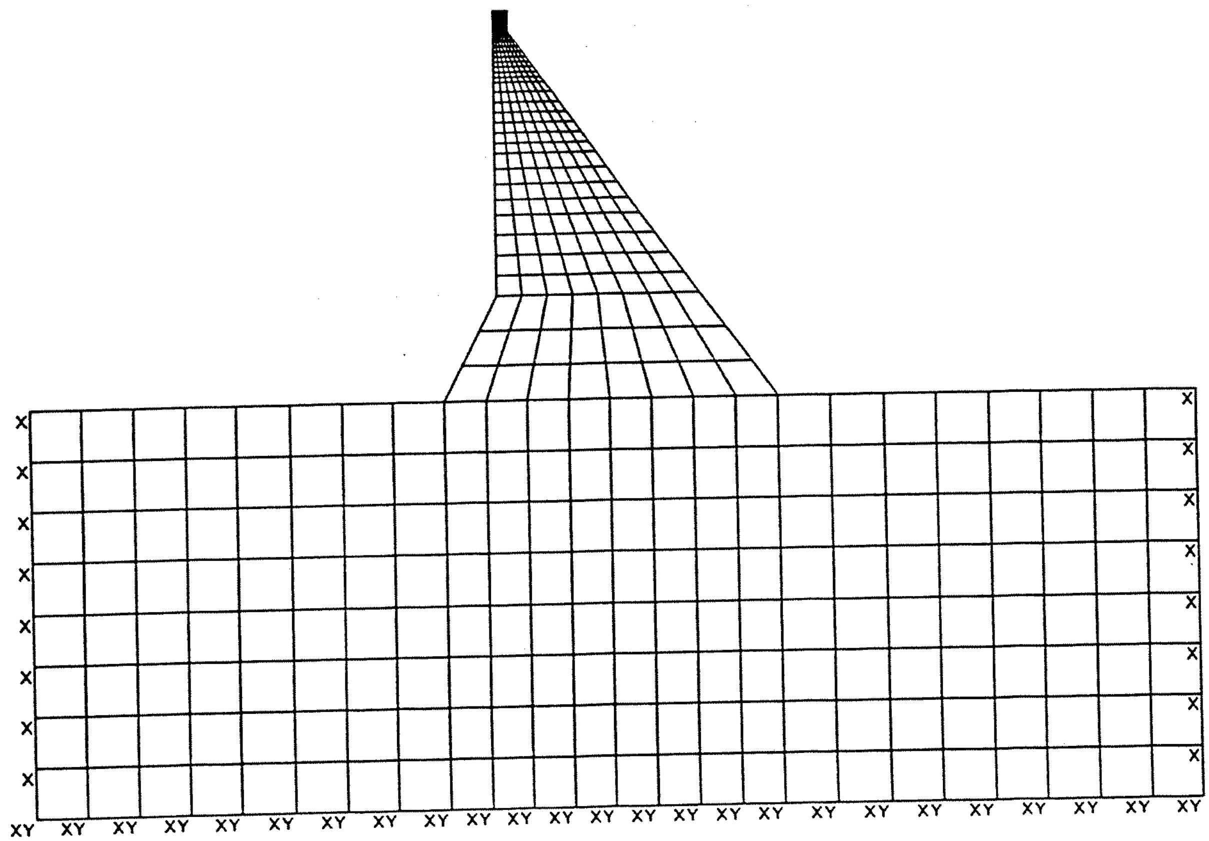


Figure 7

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Finite Element Model Dam and Foundation

Geom file=shastadam.elem

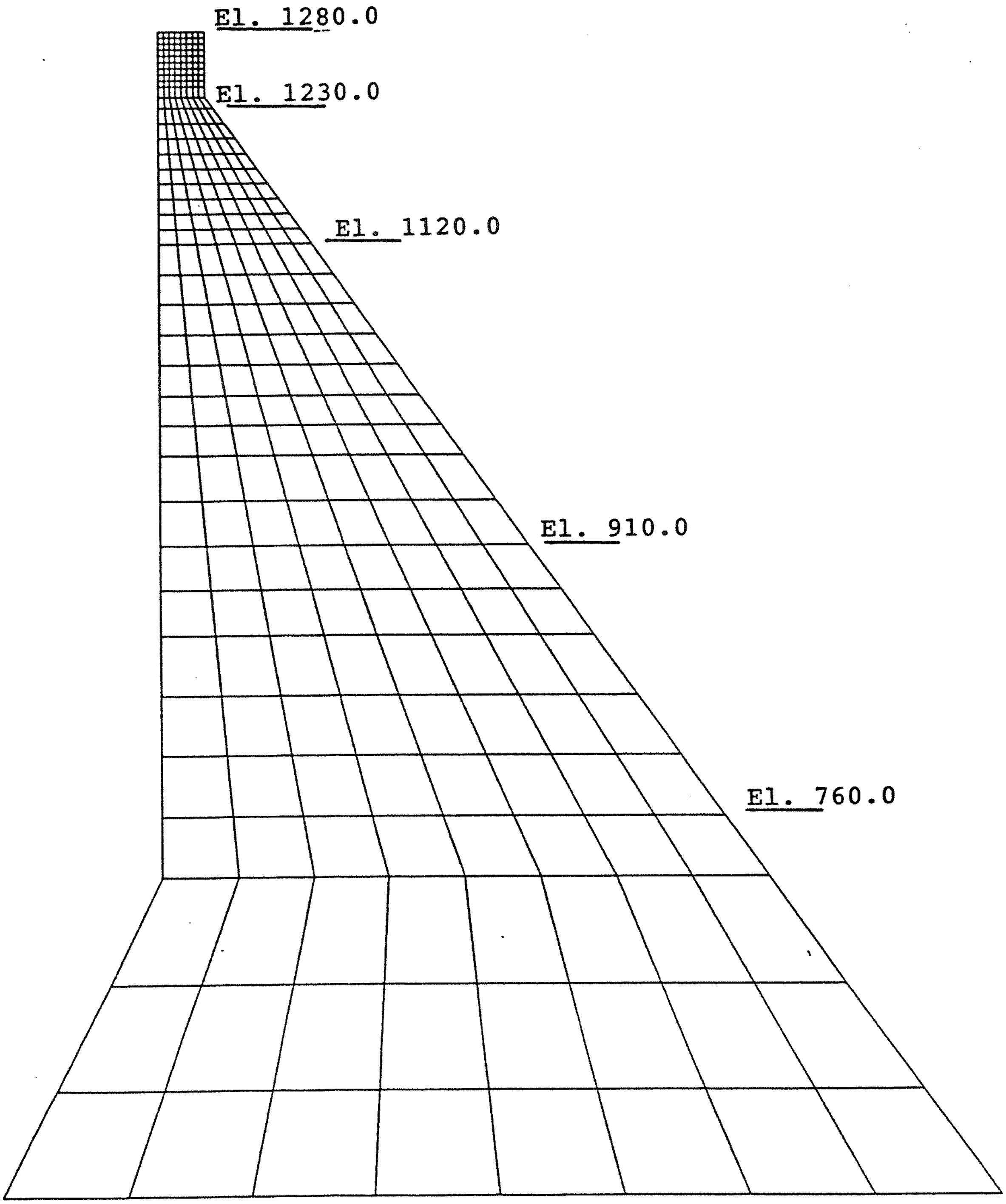


Input=shastadam.p2p, Created 3-Feb-98 09:08:20

Figure 8

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Geom file=shastadam.elem



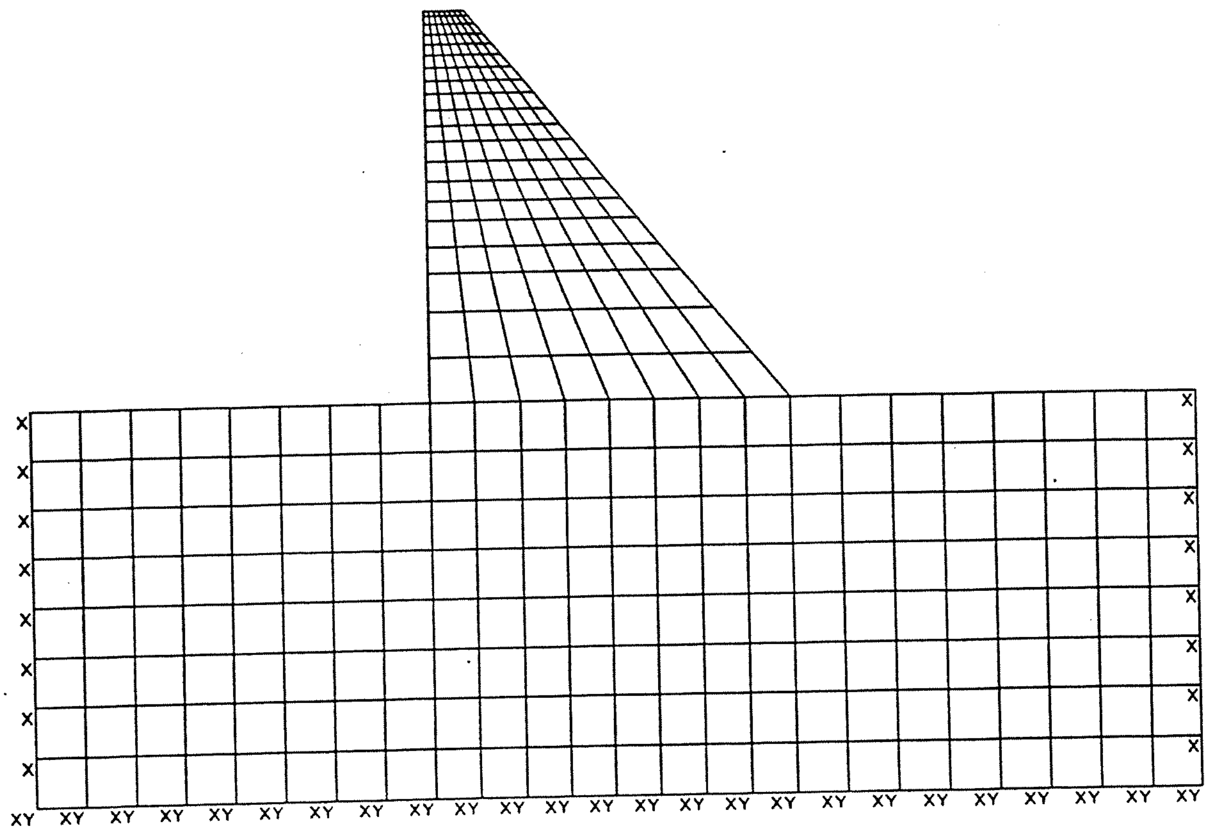
Input=shdamf2.p2p, Created 3-Feb-98 10:18:33

Figure 9

SHASTA DAM - 300 ft. High RCC - 0.80: 1

Finite Element Model Dam and Foundation

Geom file=shrcc.elem



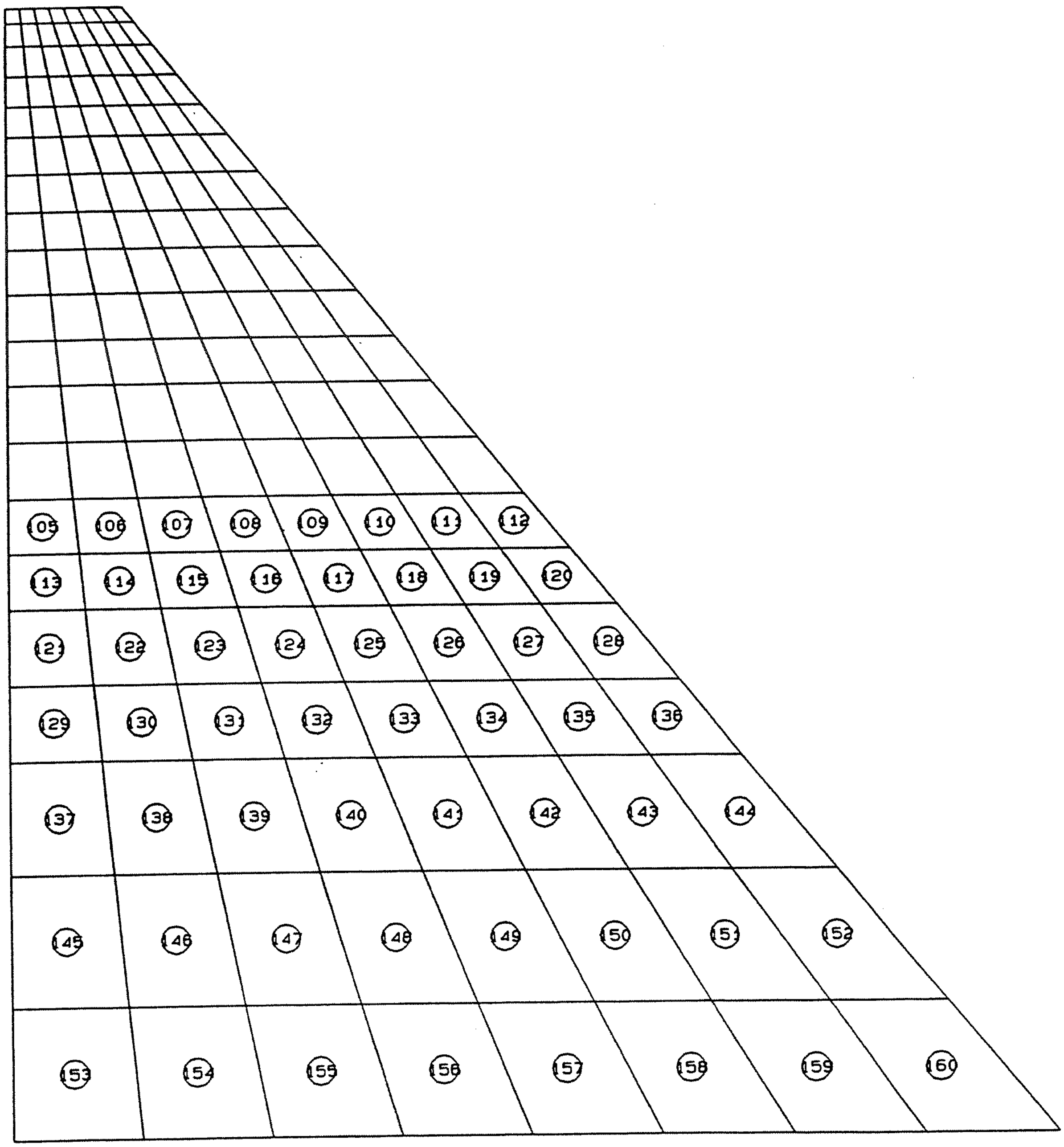
Input=shastadam.p2p. Created 7-Feb-98 10:45:02

Figure 10

SHASTA DAM - 300 ft. High RCC - 0.80: 1

Finite Element Model Dam Only

Geom file=shrcc.elem



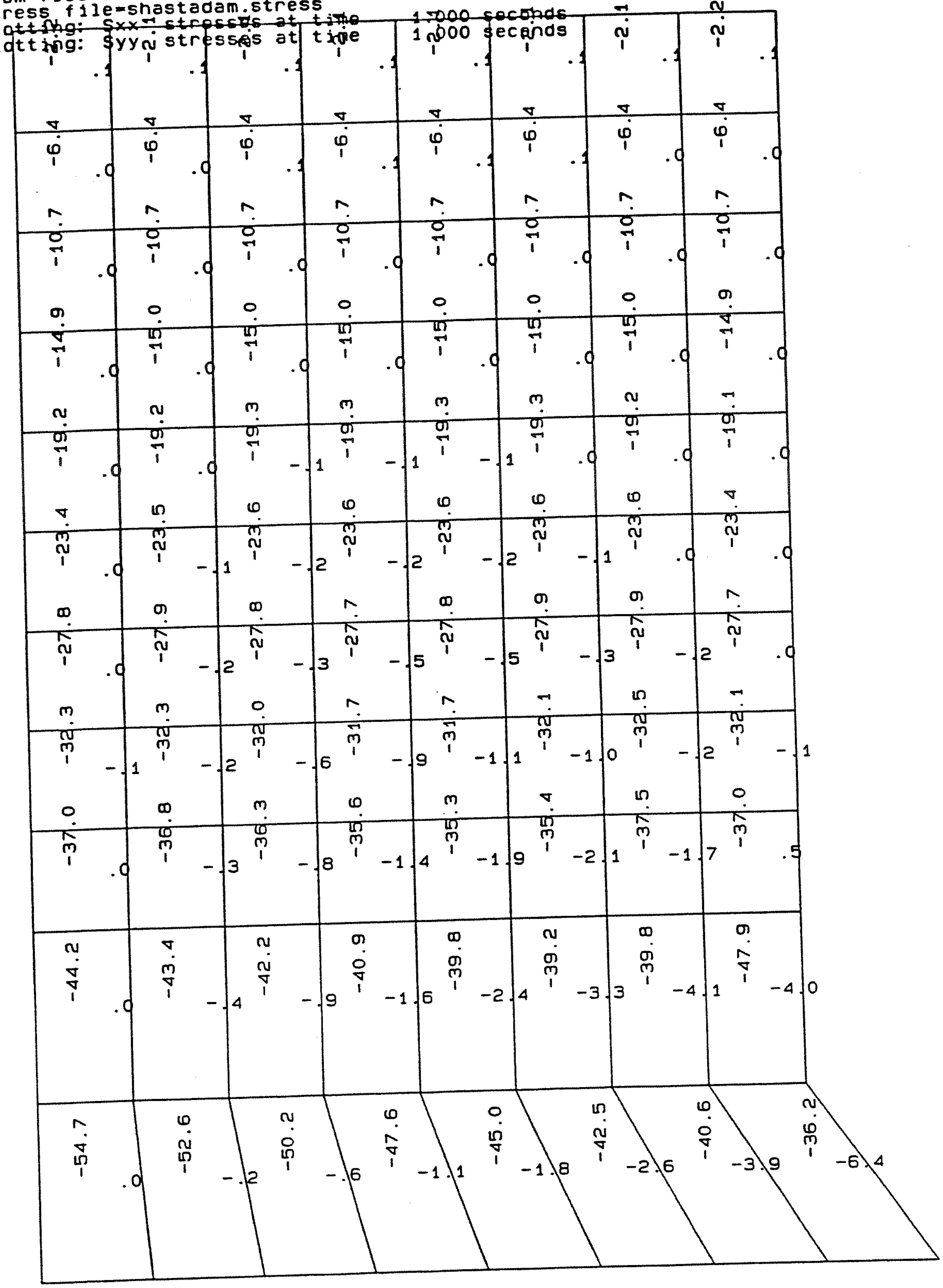
Input=shastadam.p2p. Created 7-Feb-98 11:08:51

Figure 1

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity Load Only - El. 1280.0 - 1230.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 1.000 seconds
Plotting: Syy stresses at time 1.000 seconds



Sxx and Syy (psi)

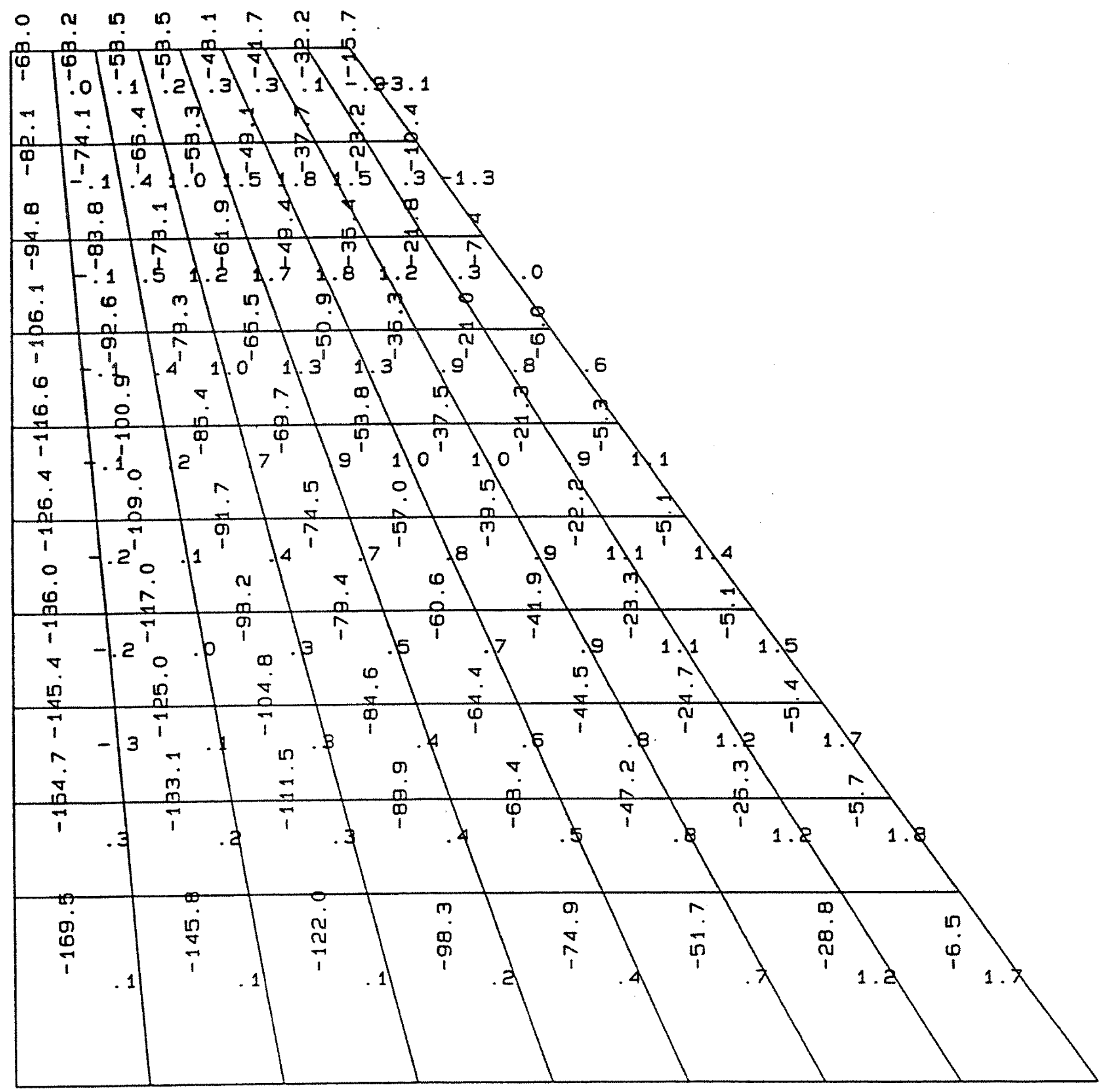
Input=sht1.p2p. Created 3-Feb-98 10:05:02

Figure 12a

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity Load Only - El. 1230.0 - 1120.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 1.000 seconds
Plotting: Syy stresses at time 1.000 seconds



Sxx and Syy (psi)

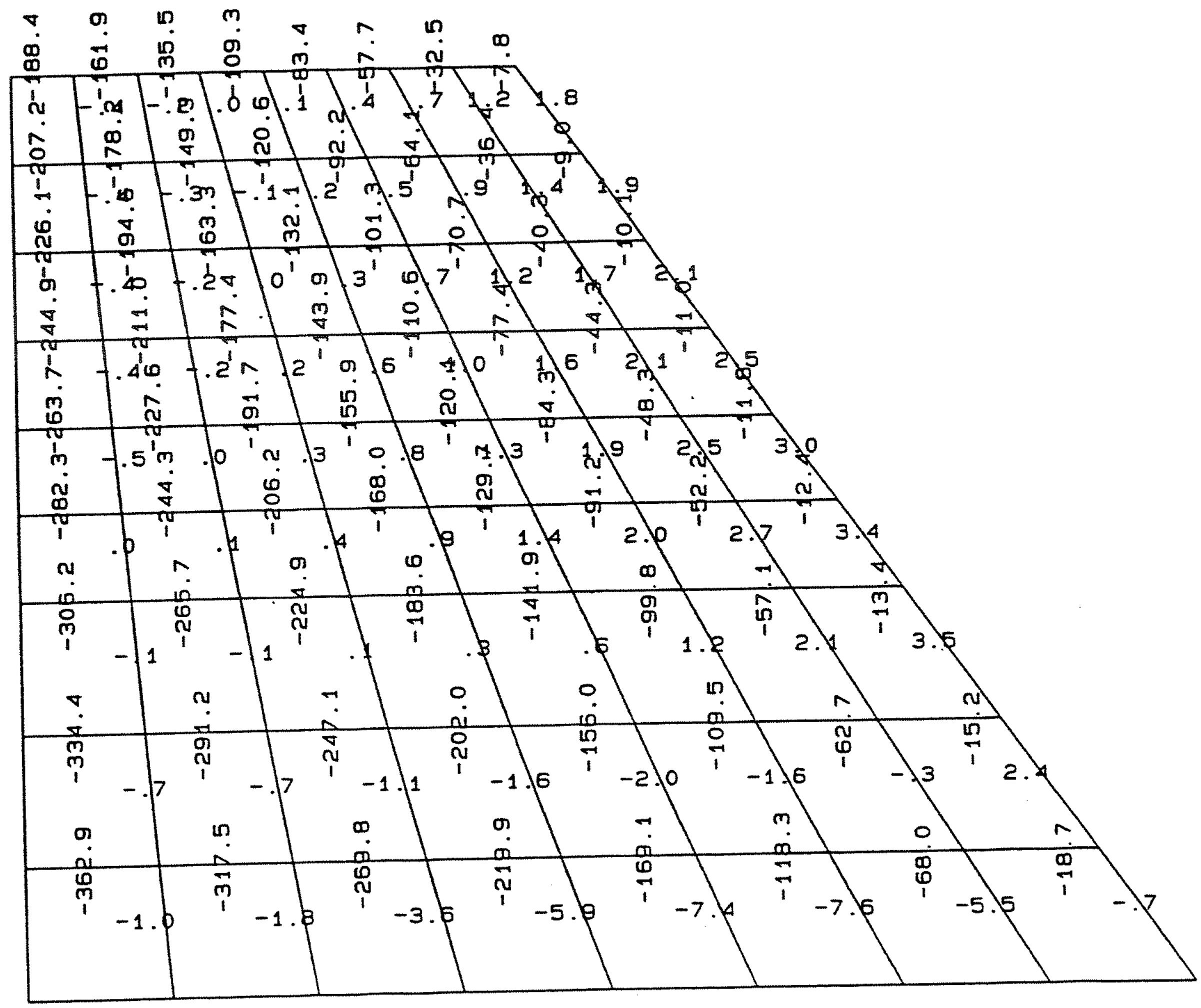
Input=sht2.p2p, Created 3-Feb-98 10:07:26

Figure 12

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity Load Only - El. 1120.0 - 910.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 1.000 seconds
Plotting: Syy stresses at time 1.000 seconds



Sxx and Syy (psi)

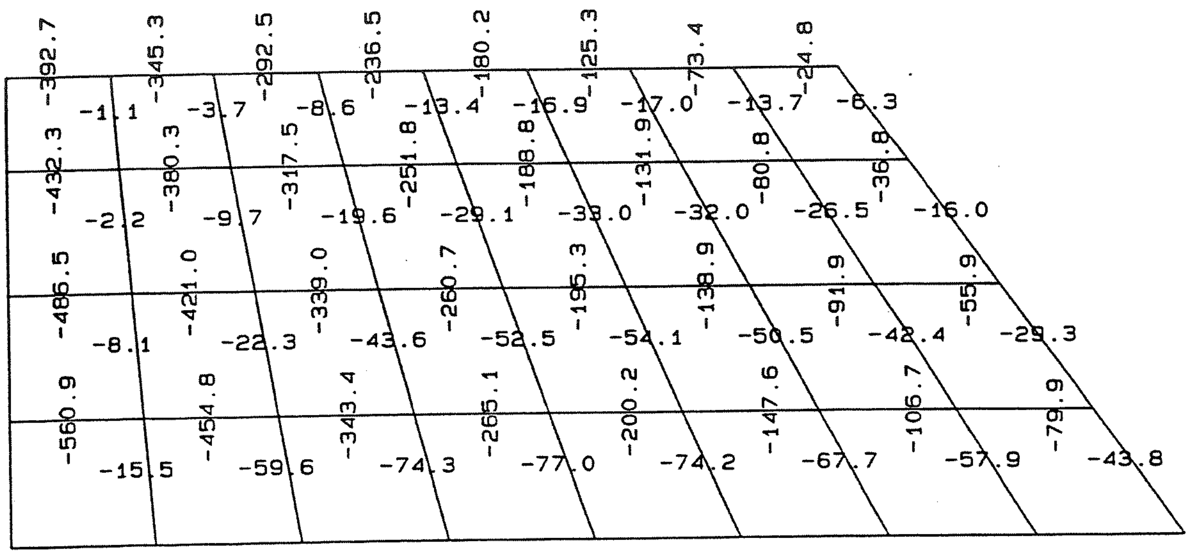
Input=sht3.p2p, Created 3-Feb-98 10:12:37

Figure 12c

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity Load Only - El. 910.0 - 760.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 1.000 seconds
Plotting: Syy stresses at time 1.000 seconds



Sxx and Syy (psi)

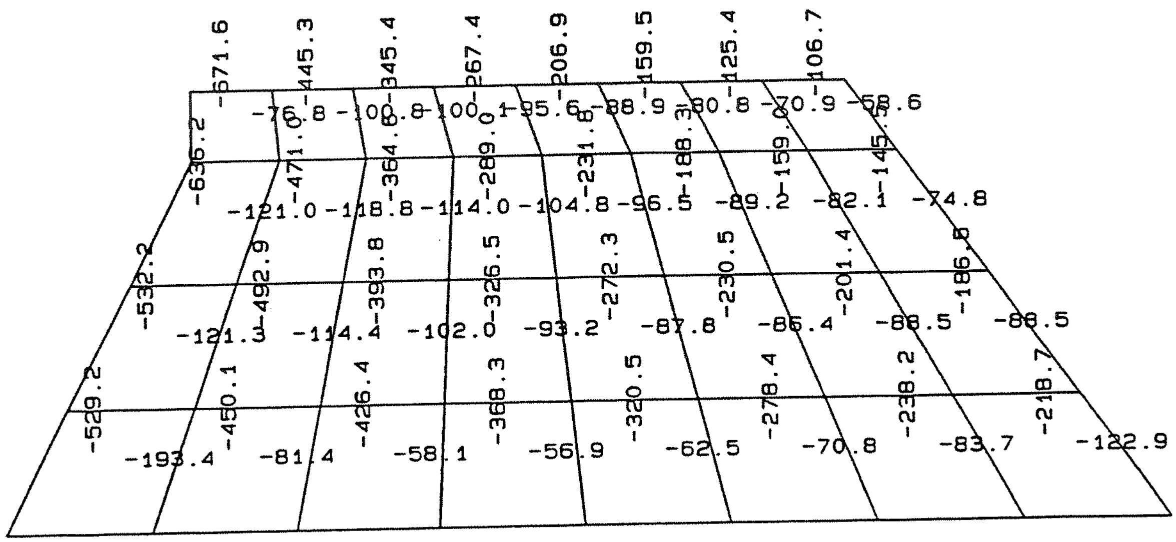
Input=sht4.p2p. Created 3-Feb-98 10:20:57

Figure 12

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity Load Only - El. 760.0 - 510.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 1.000 seconds
Plotting: Syy stresses at time 1.000 seconds



Sxx and Syy (psi)

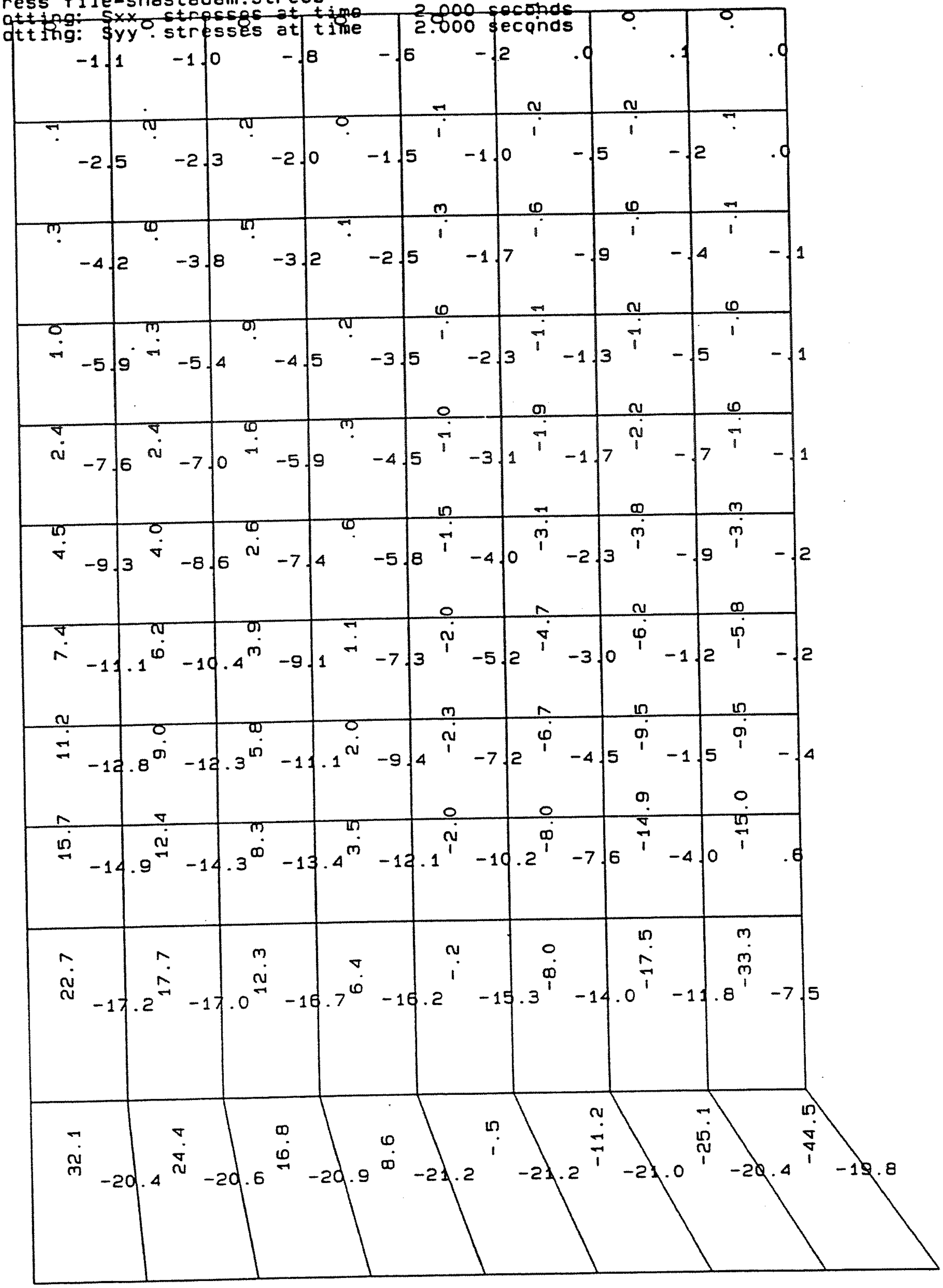
Input=sht5.p2p. Created 3-Feb-98 10:24:07

Figure 12e

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

RWS at 1280.0 Only - El. 1280.0 - 1230.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 2.000 seconds
Plotting: Syy stresses at time 2.000 seconds



Sxx and Syy (psi)

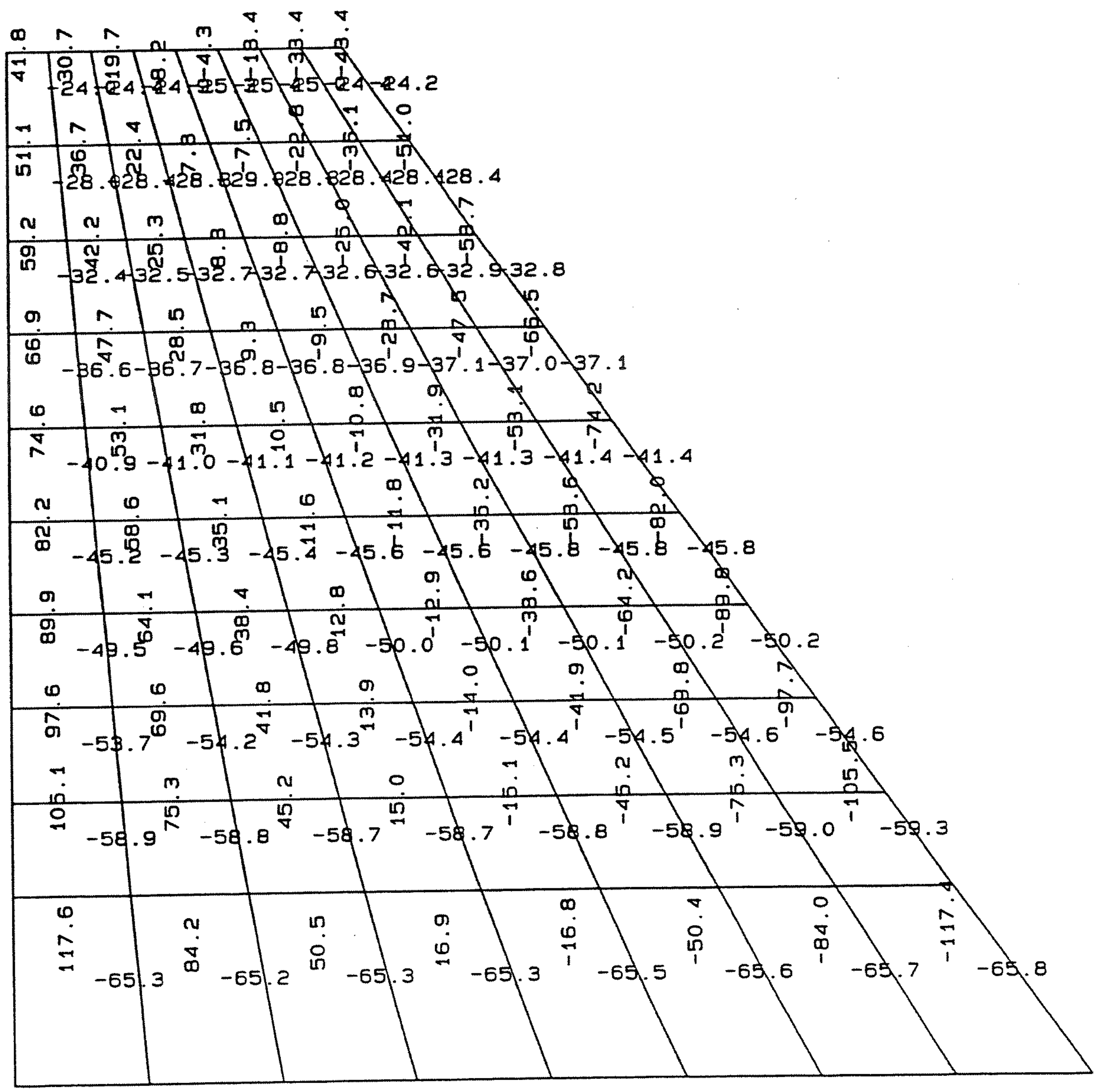
Input=sht1.p2p. Created 3-Feb-98 10:26:09

Figure 13

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

RWS at 1280.0 Only - El. 1230.0 - 1120.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 2.000 seconds
Plotting: Syy stresses at time 2.000 seconds



Sxx and Syy (psi)

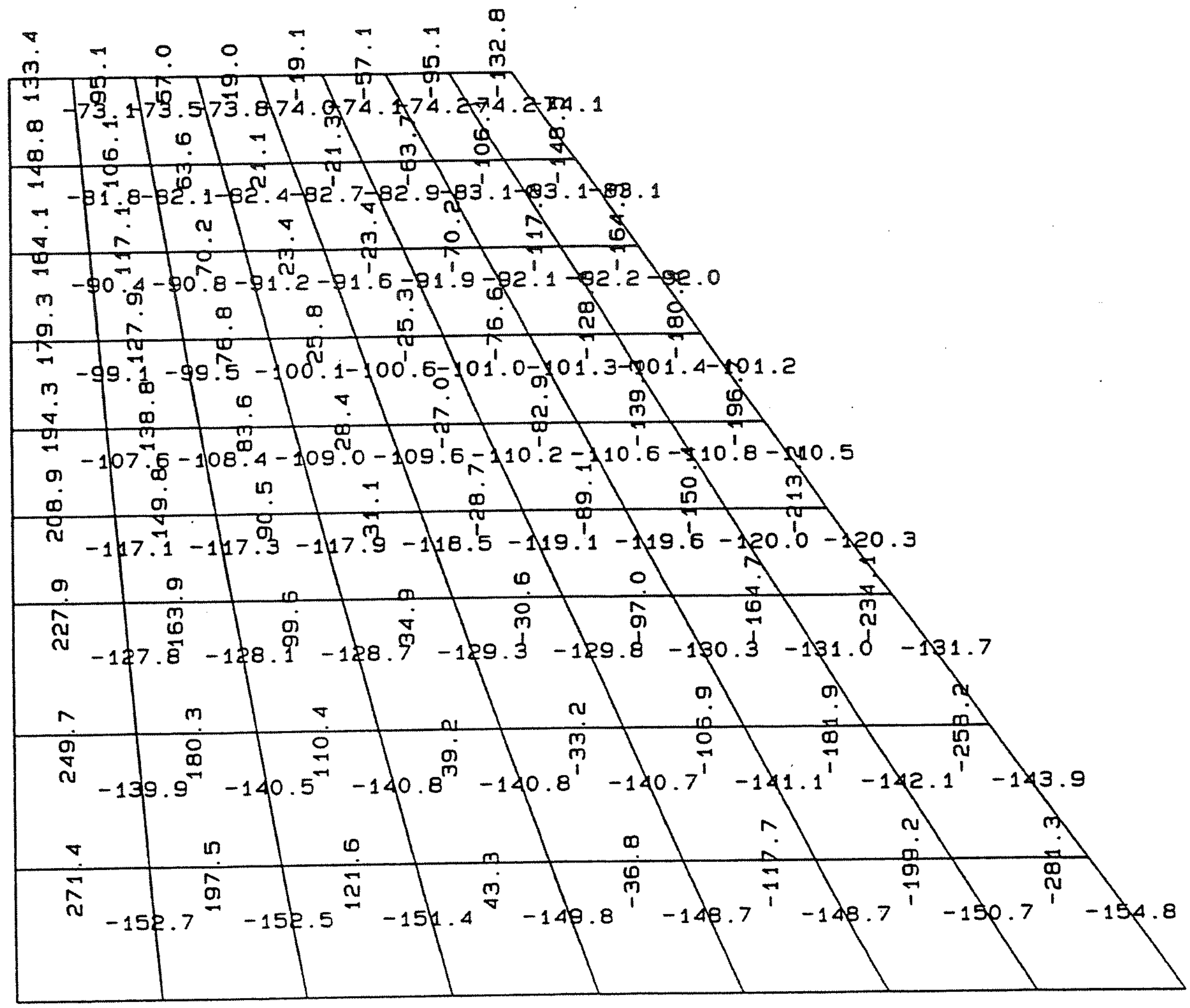
Input=sht2.p2p, Created 3-Feb-98 10:31:53

Figure 13b

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

RWS at 1280.0 Only - El. 1120.0 - 910.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 2.000 seconds
Plotting: Syy stresses at time 2.000 seconds



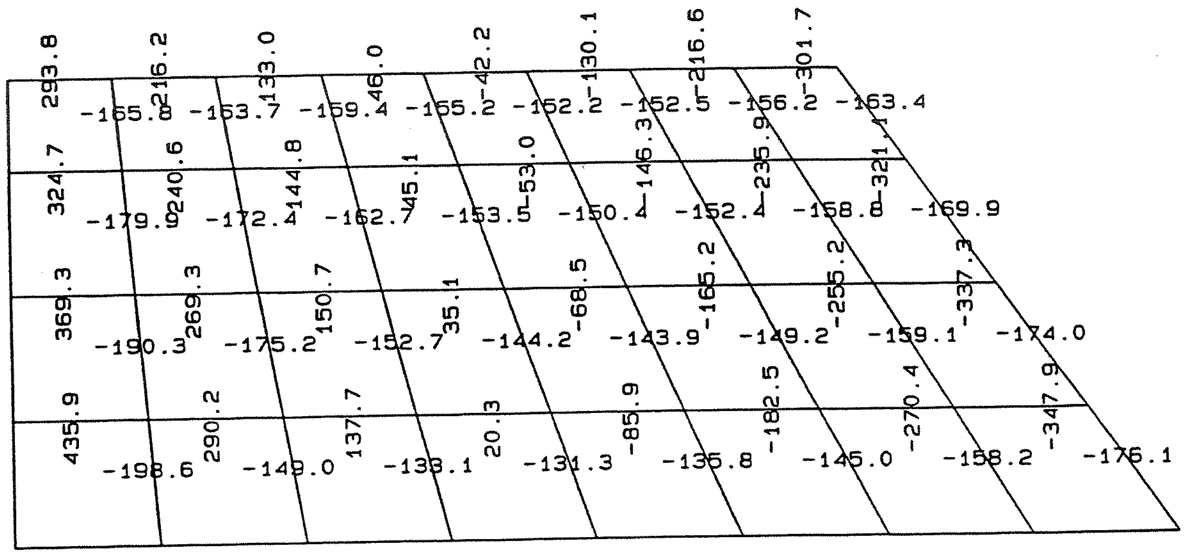
Sxx and Syy (psi)

Input=sht3.p2p, Created 3-Feb-98 10:33:15

Figure 13

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1
RWS at 1280.0 Only - El. 910.0 - 760.0

Geom file-shastadam.elem
Stress file-shastadam.stress
Plotting: Sxx stresses at time 2.000 seconds
Plotting: Syy stresses at time 2.000 seconds



Sxx and Syy (psi)

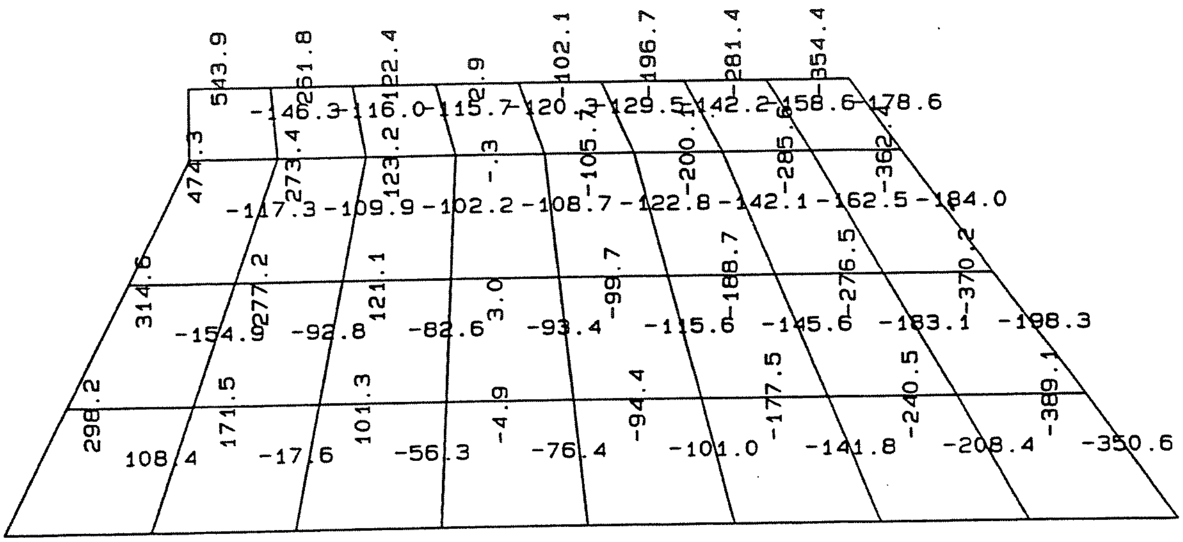
Input-sht4.p2p, Created 3-Feb-98 10:34:46

Figure 13d

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

RWS at 1280.0 Only - El. 760.0 - 510.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 2.000 seconds
Plotting: Syy stresses at time 2.000 seconds



Sxx and Syy (psi)

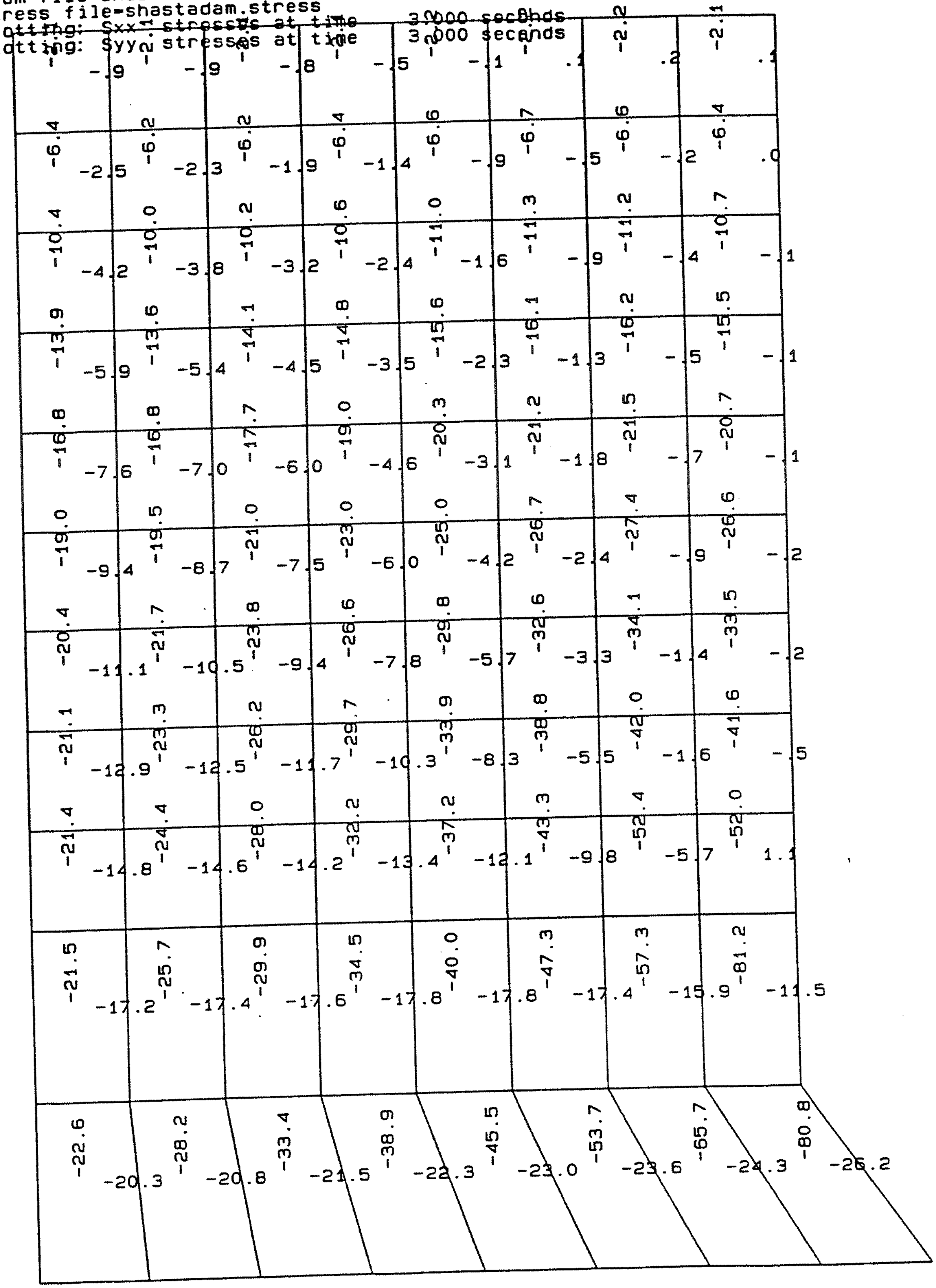
Input=sht5.p2p. Created 3-Feb-98 10:36:07

Figure 1

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity and RWS at 1280.0 - El. 1280.0 - 1230.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 3.000 seconds
Plotting: Syy stresses at time 3.000 seconds



Sxx and Syy (psi)

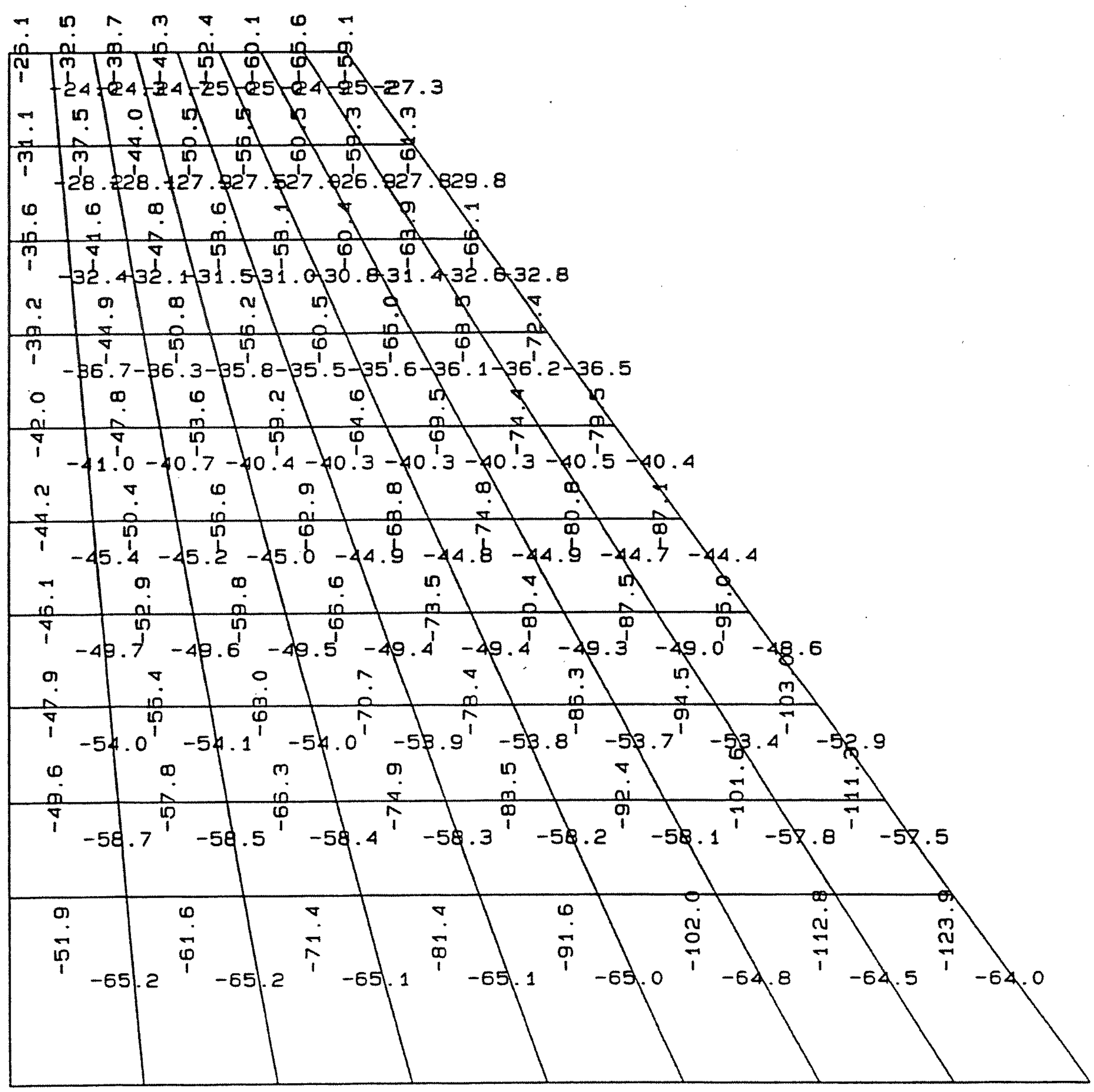
Input=sht1.p2p, Created 3-Feb-98 10:38:02

Figure 14a

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity and RWS at 1280.0 - El. 1230.0 - 1120.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 3.000 seconds
Plotting: Syy stresses at time 3.000 seconds



Sxx and Syy (psi)

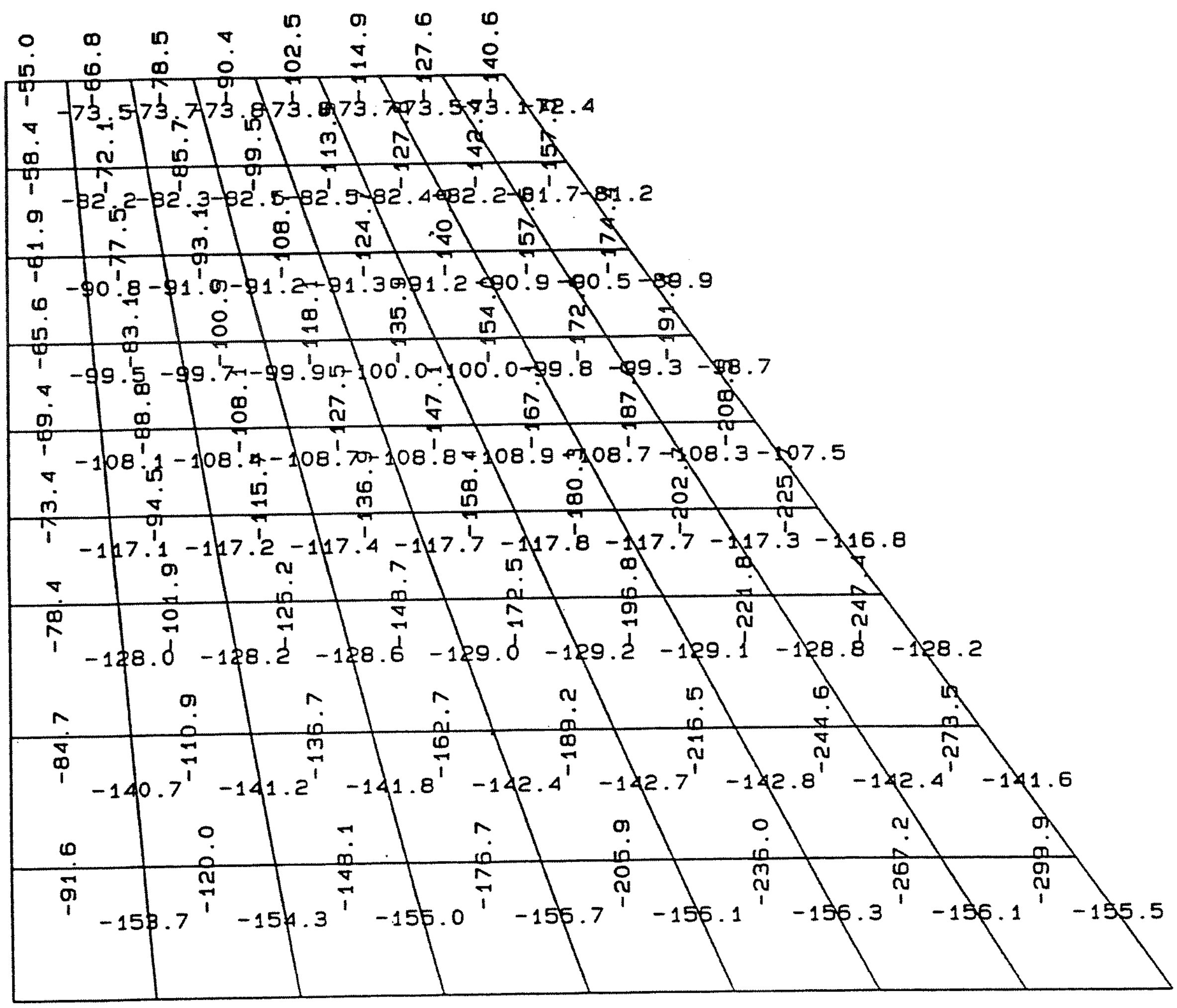
Input=sht2.p2p. Created 3-Feb-98 10:51:47

Figure 14

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity and RWS at 1280.0 - El. 1120.0 - 910.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 3.000 seconds
Plotting: Syy stresses at time 3.000 seconds



Sxx and Syy (psi)

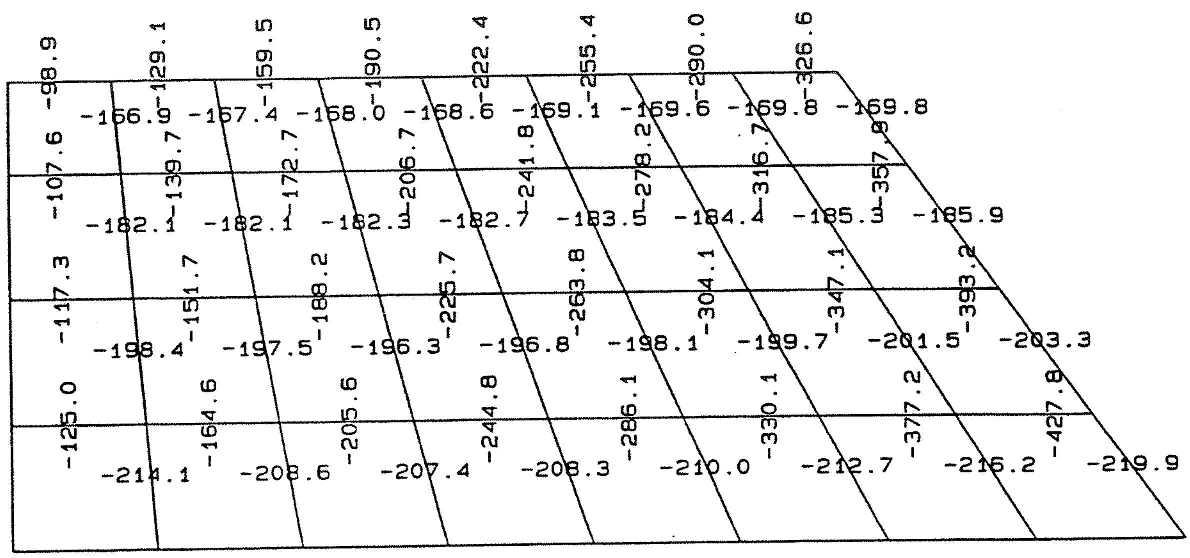
Input=sht3.p2p, Created 3-Feb-98 10:53:03

Figure 14c

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity and RWS at 1280.0 - El. 910.0 - 760.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 3.000 seconds
Plotting: Syy stresses at time 3.000 seconds



Sxx and Syy (psi)

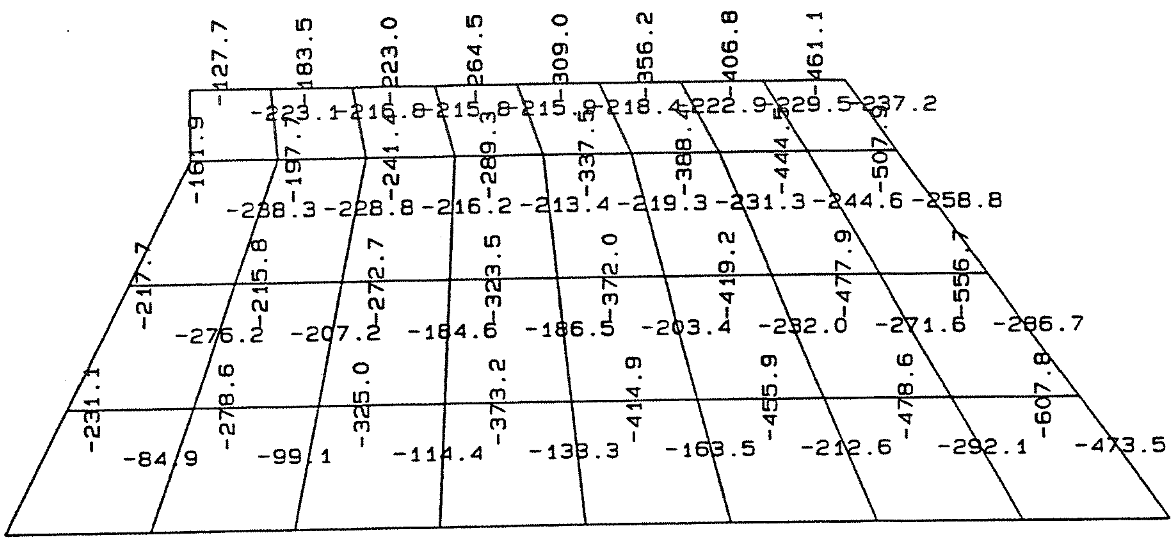
Input=sht4.p2p. Created 3-Feb-98 10:54:12

Figure 14c

SHASTA DAM RAISE - EL. 1280.0 - 0.70: 1

Gravity and RWS at 1280.0 - El. 760.0 - 510.0

Geom file=shastadam.elem
Stress file=shastadam.stress
Plotting: Sxx stresses at time 3.000 seconds
Plotting: Syy stresses at time 3.000 seconds



Sxx and Syy (psi)

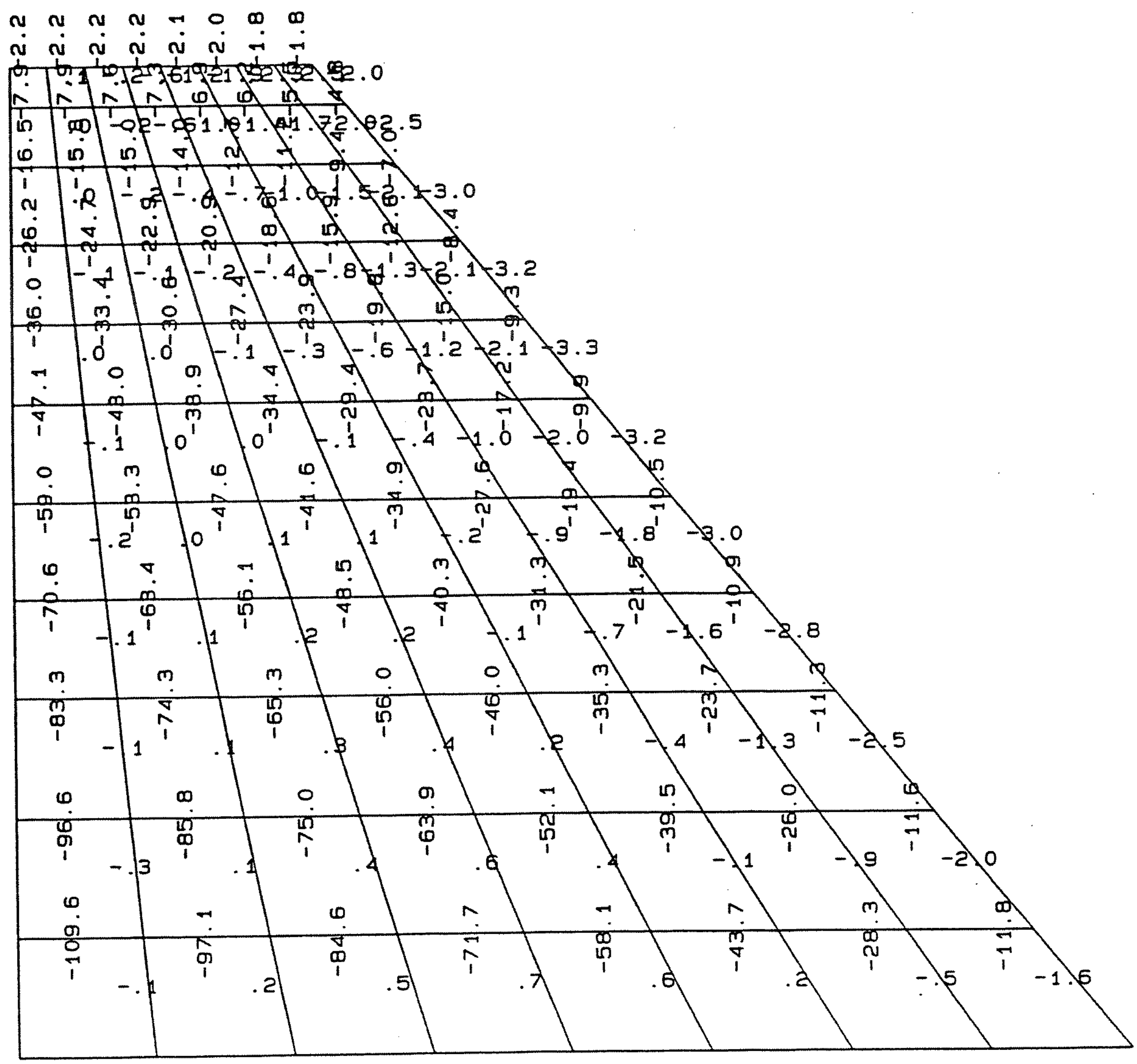
Input=sht5.p2p, Created 3-Feb-98 10:55:21

Figure 14e

SHASTA DAM 300ft High RCC - 0.80:1

Gravity Loading Only

Geom file=shrcc.elem
Stress file=shrcc.stress
Plotting: Sxx stresses at time 1.000 seconds
Plotting: Syy stresses at time 1.000 seconds



Sxx and Syy Stresses (psi)

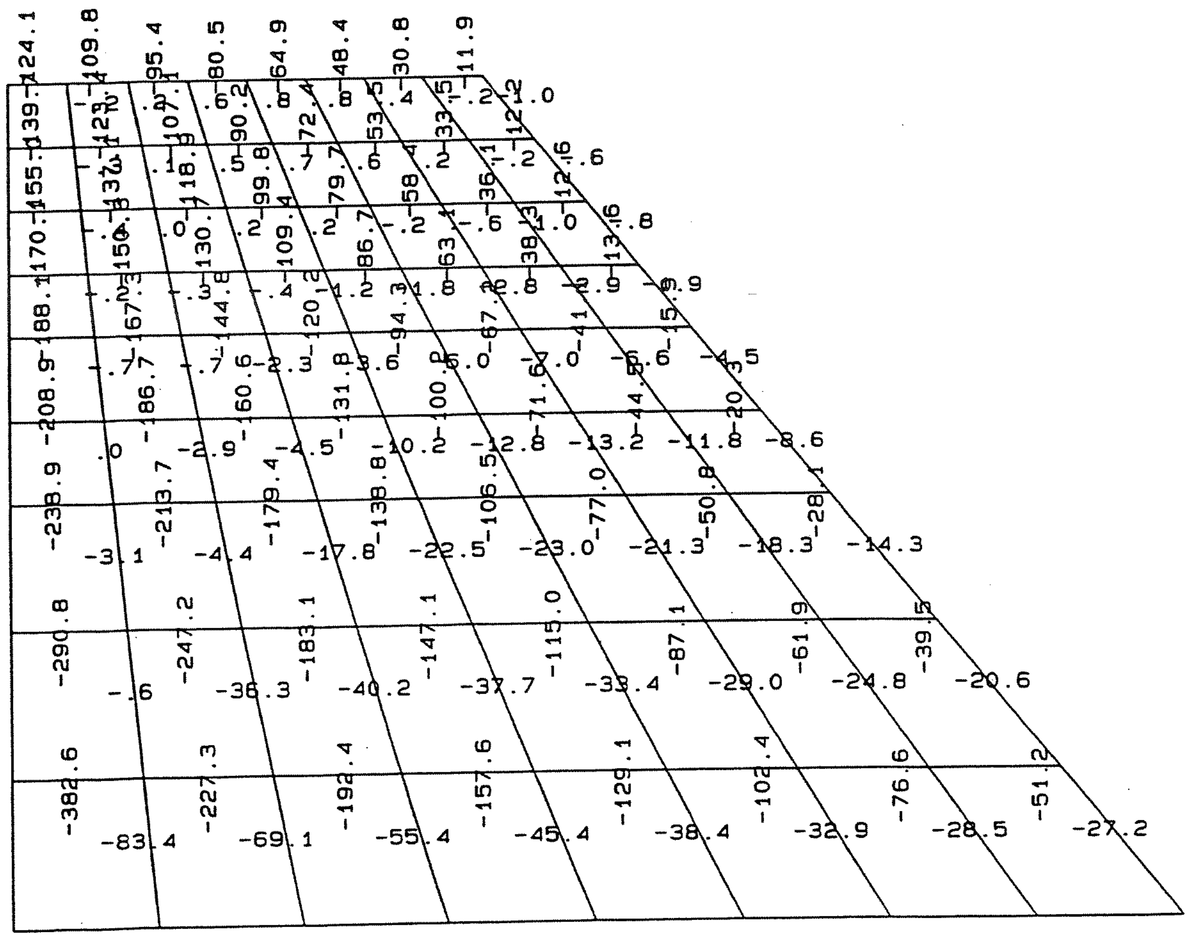
Input=plt2df3.p2p. Created 7-Feb-98 12:24:59

Figure 15

SHASTA DAM 300ft High RCC - 0.80: 1

Gravity Load Only

Geom file=shrcc.elem
Stress file=shrcc.stress
Plotting: Sxx stresses at time 1.000 seconds
Plotting: Syy stresses at time 1.000 seconds



Sxx and Syy Stresses (psi)

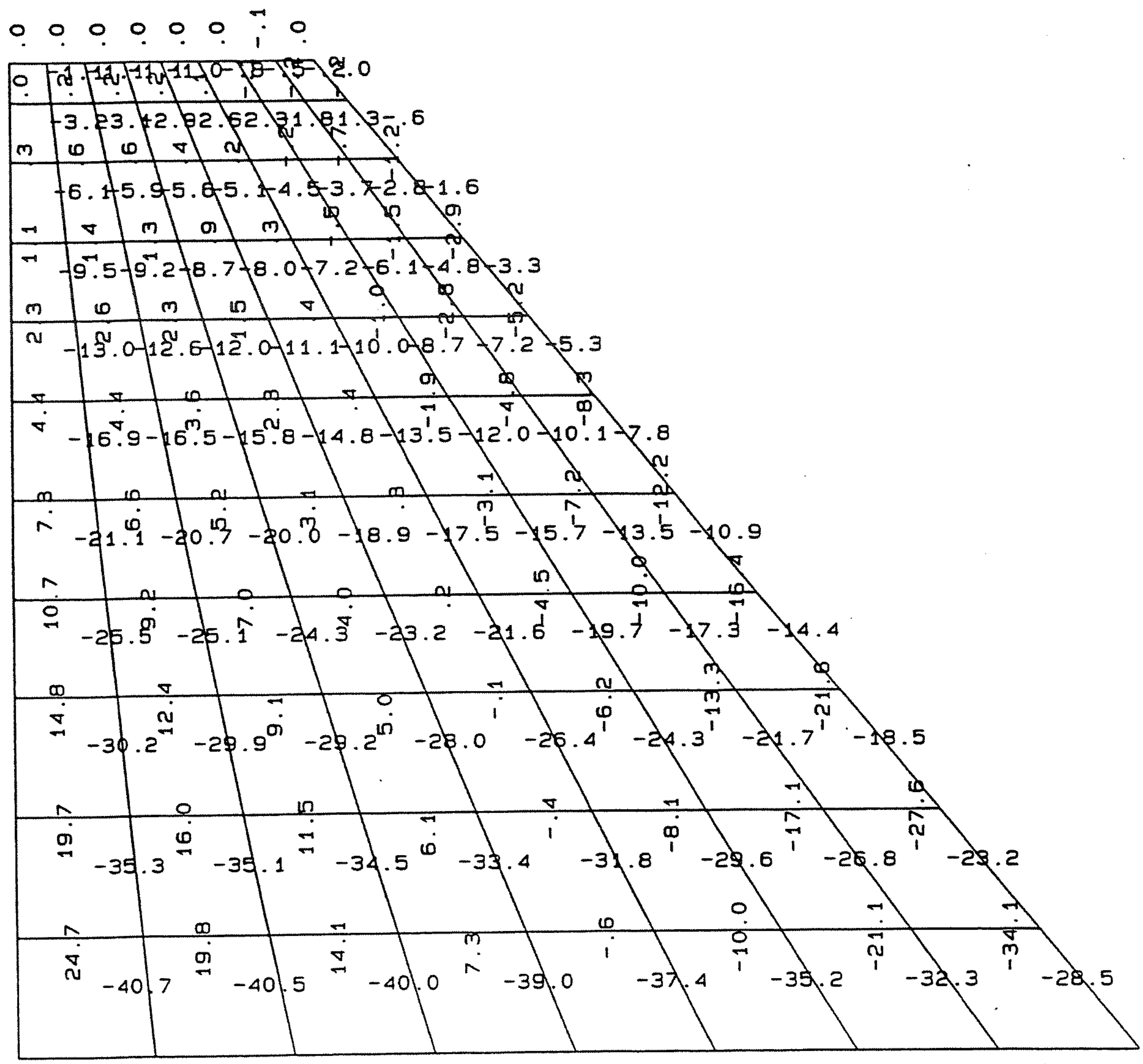
Input=plt2df3.p2p. Created 7-Feb-98 12:10:57

Figure 15b

SHASTA DAM 300ft High RCC - 0.80: 1

Reservoir (El. 1280.0) Loading Only

Geom file=shrcc.elem
Stress file=shrcc.stress
Plotting: Sxx stresses at time 2.000 seconds
Plotting: Syy stresses at time 2.000 seconds



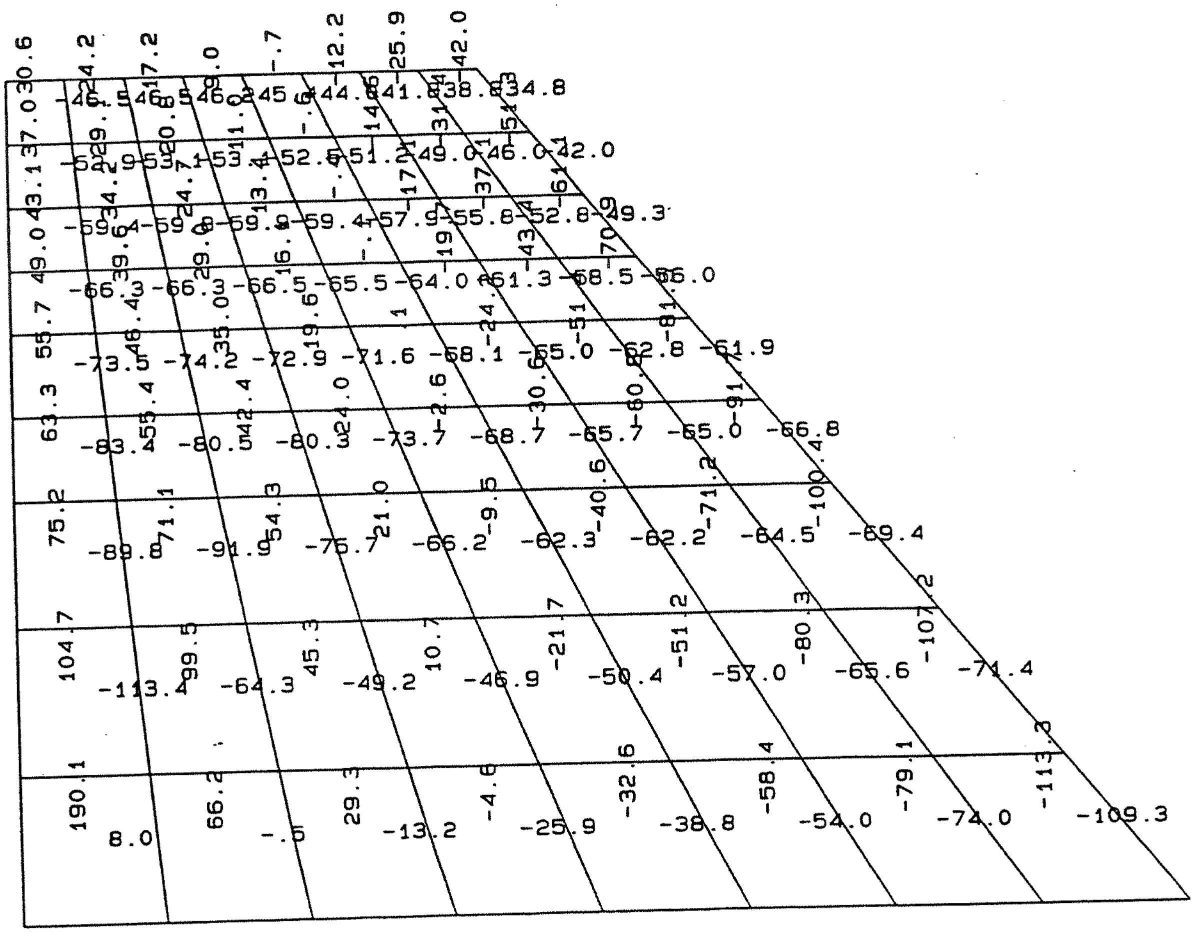
Sxx and Syy Stresses (psi)

Input=plt2df3.p2p. Created 7-Feb-98 12:23:45

Figure 16a

SHASTA DAM 300ft High RCC - 0.80: 1
Reservoir (El 1280.0) Load Only

Geom file=shrcc.elem
Stress file=shrcc.stress
Plotting: Sxx stresses at time 2.000 seconds
Plotting: Syy stresses at time 2.000 seconds



Sxx and Syy Stresses (psi)

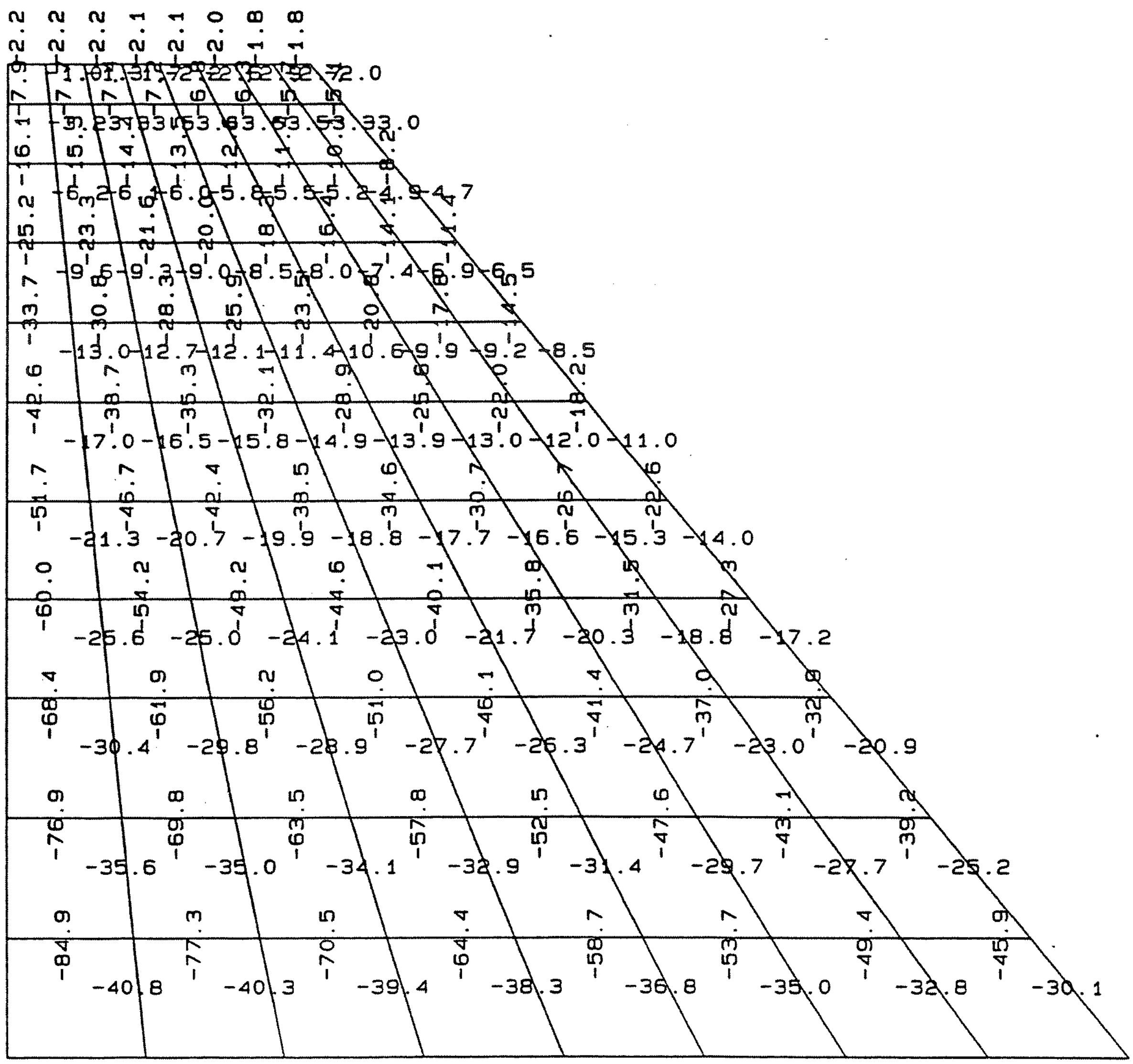
Input=plt2df3.p2p. Created 7-Feb-98 12:09:15

Figure 16b

SHASTA DAM 300ft High RCC - 0.80: 1

Gravity and Reservoir (El. 1280.0)

Geom file=shrcc.elem
Stress file=shrcc.stress
Plotting: Sxx stresses at time 3.000 seconds
Plotting: Syy stresses at time 3.000 seconds



Sxx and Syy Stresses (psi)

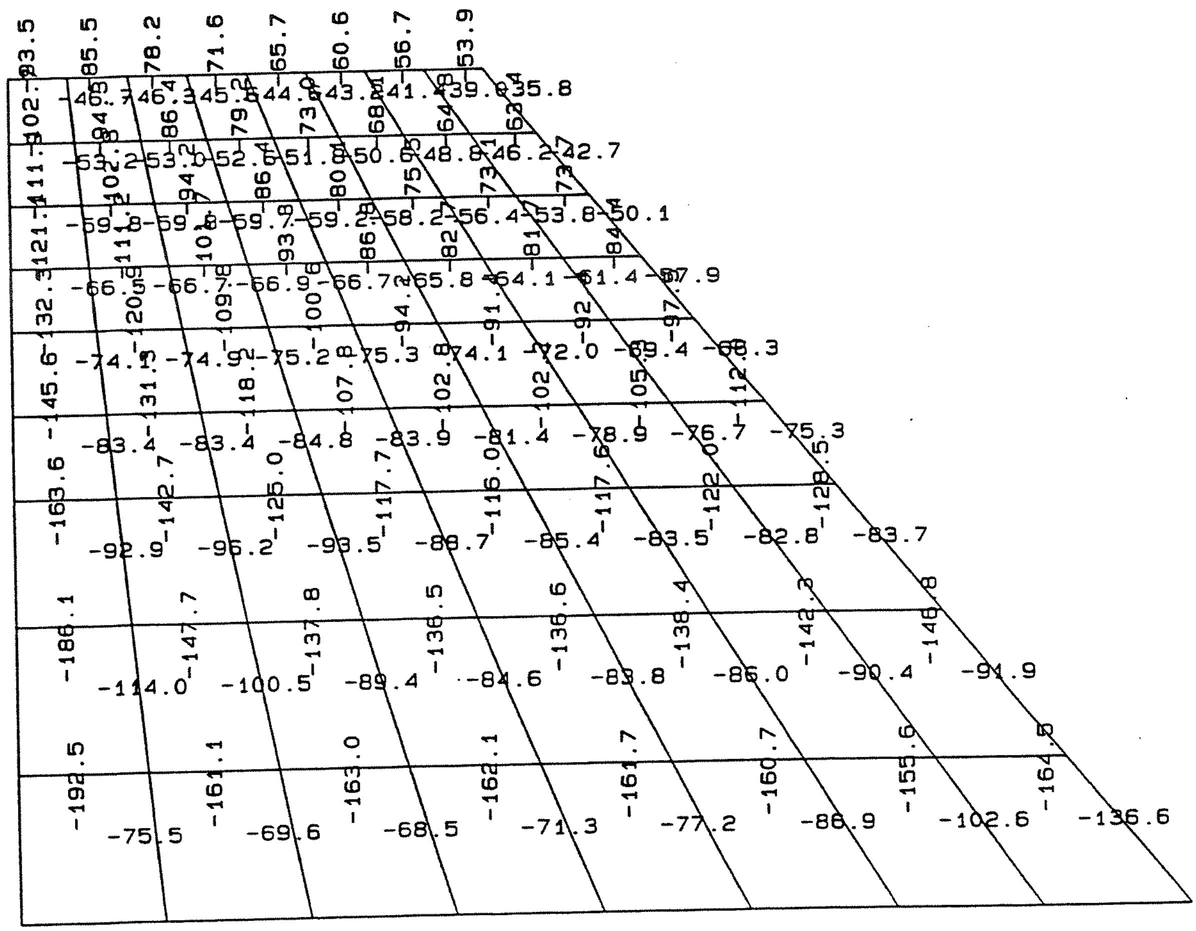
Input=plt2df3.p2p, Created 7-Feb-98 12:17:24

Figure 17a

SHASTA DAM 300ft High RCC - 0.80: 1

Gravity and Reservoir (El. 1280.0)

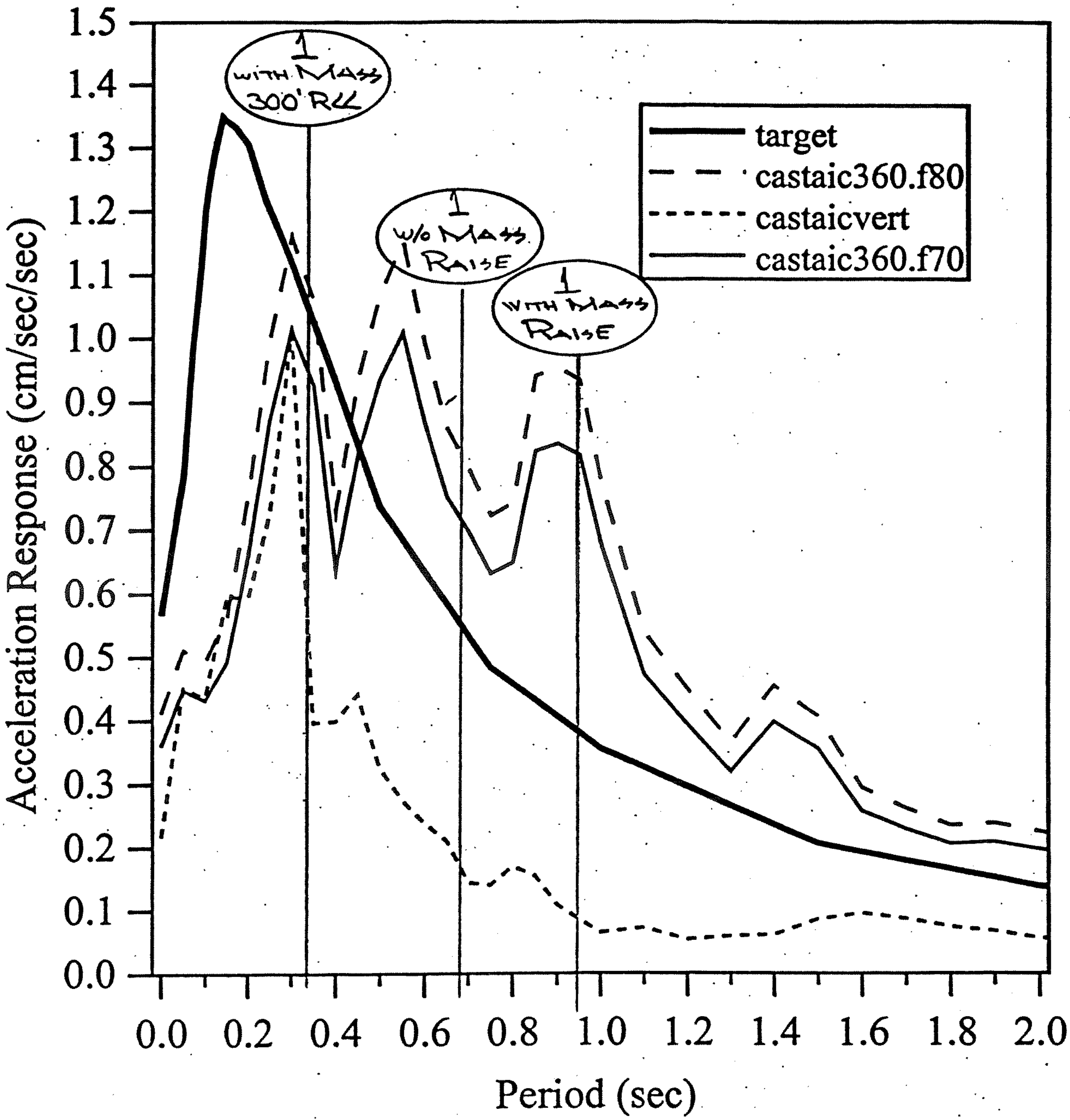
Geom file=shrcc.elem
Stress file=shrcc.stress
Plotting: Sxx stresses at time 3.000 seconds
Plotting: Syy stresses at time 3.000 seconds



Sxx and Syy Stresses (psi)

Input=plt2df3.p2p, Created 7-Feb-98 12:14:16

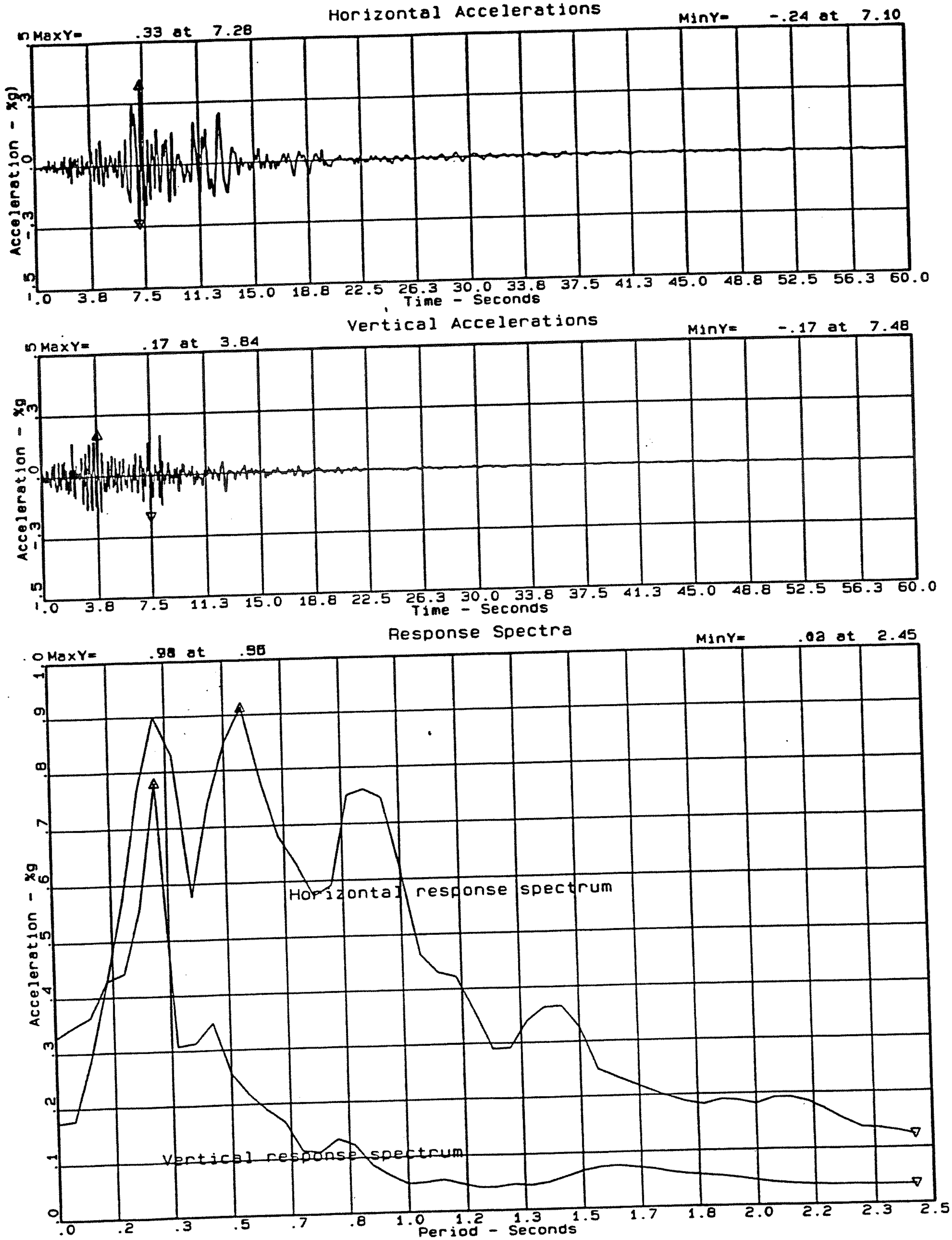
Figure 17b



Mean 50,000 years return period response spectrum for Spring Creek Debris Dam, attenuation relation of Geomatrix, 1993, rock; 360 (factors 0.8 and 0.7) and vertical components of Castaic record, Northridge 1994 earthquake.

Figure 18

Horz. factor and Vert. factor=0.80

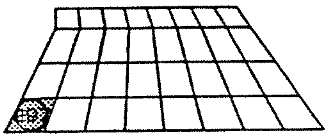


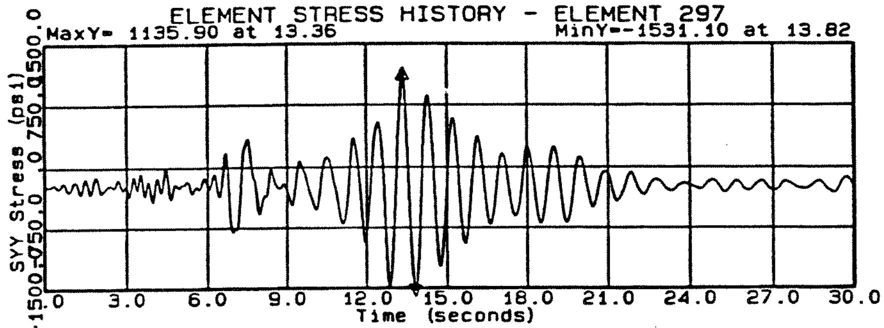
Input=h3.p2p, Created 3-Feb-98 15:20:17

Figure 19

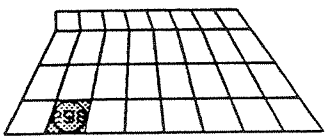
SHASTA DAM RAISE - EL.1280.0 - 0.70: 1

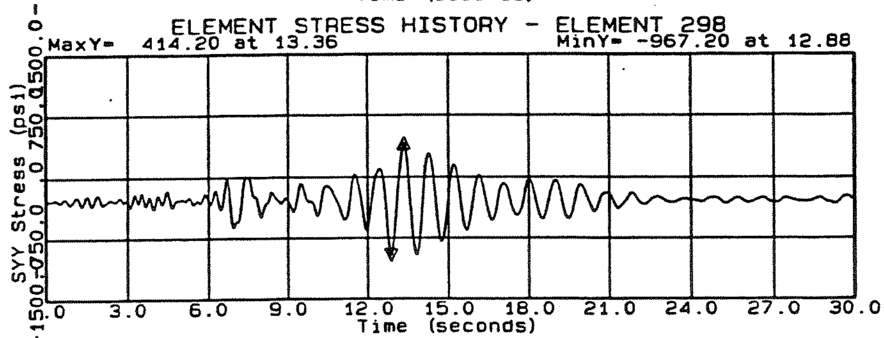
Geom file=sh07s4.elem



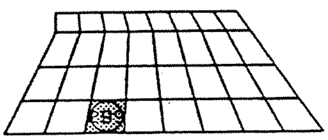


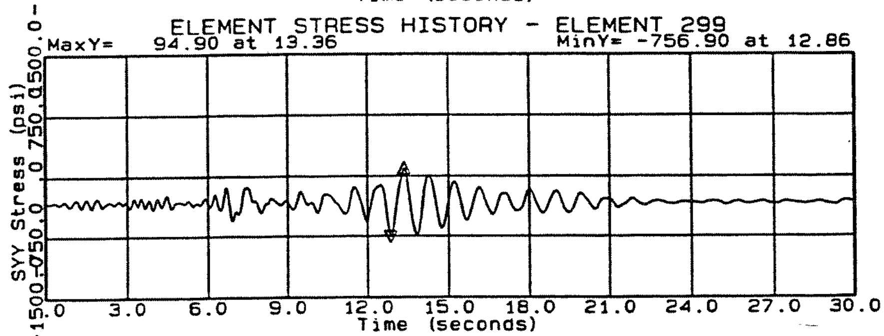
Geom file=sh07s4.elem



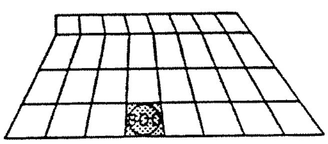


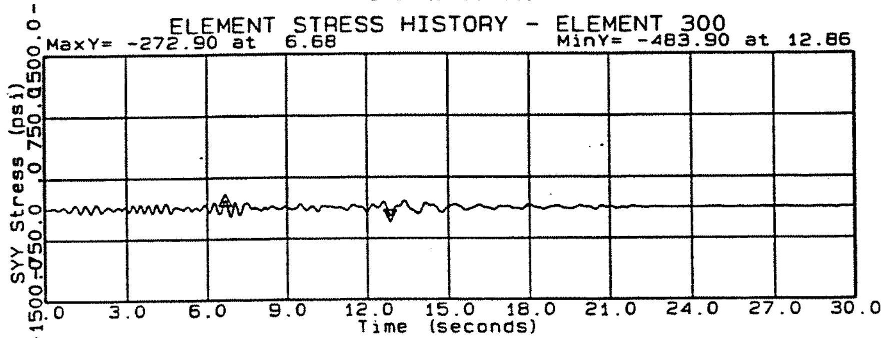
Geom file=sh07s4.elem



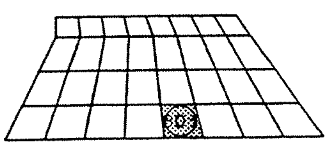


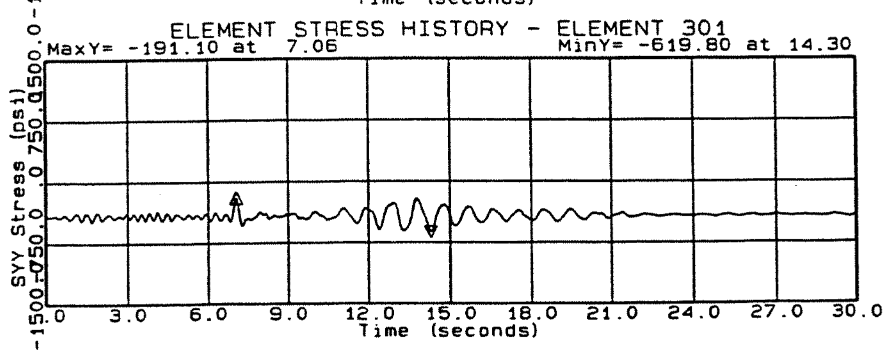
Geom file=sh07s4.elem





Geom file=sh07s4.elem



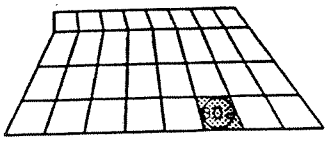


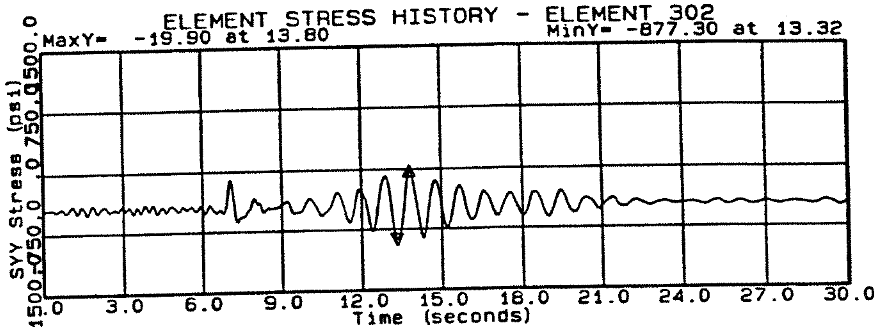
Input=streshist5.p2p. Created 6-Feb-98 07:45:00

Figure 2(

SHASTA DAM RAISE - EL.1280.0 - 0.70: 1

Geom file=sh07s4.elem





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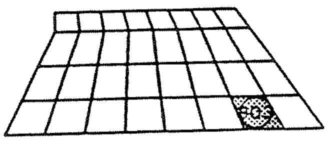
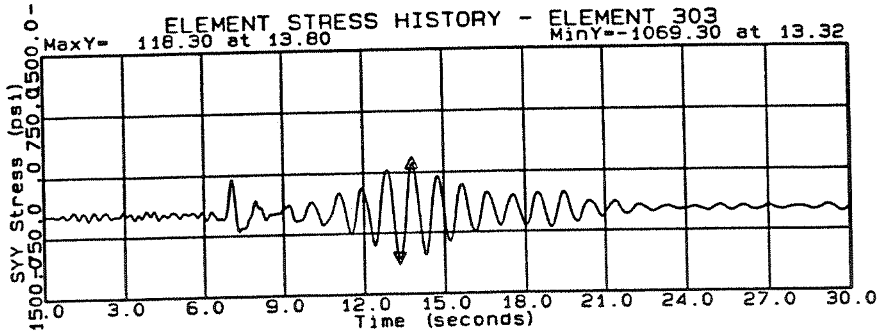
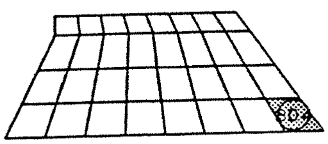
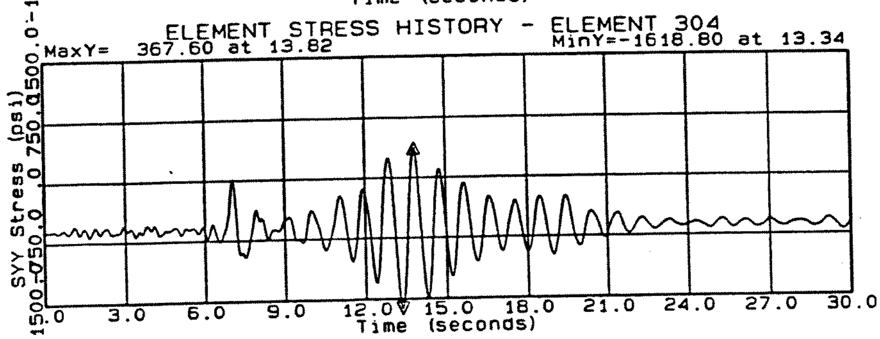


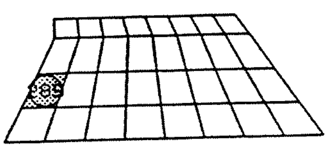


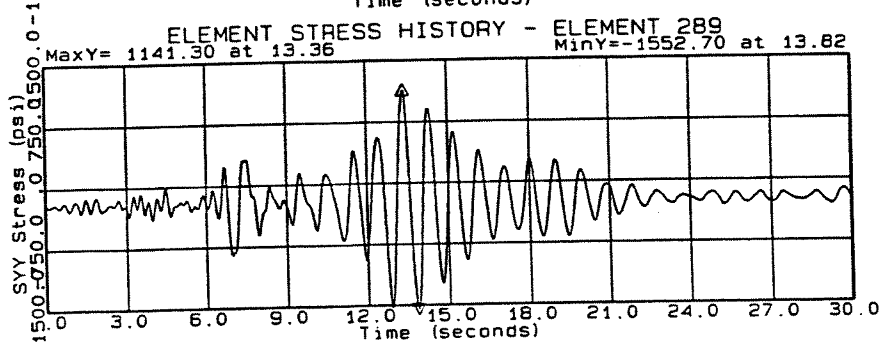
Geom file=sh07s4.elem



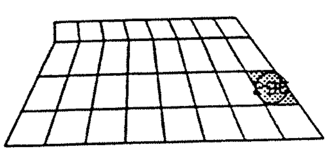


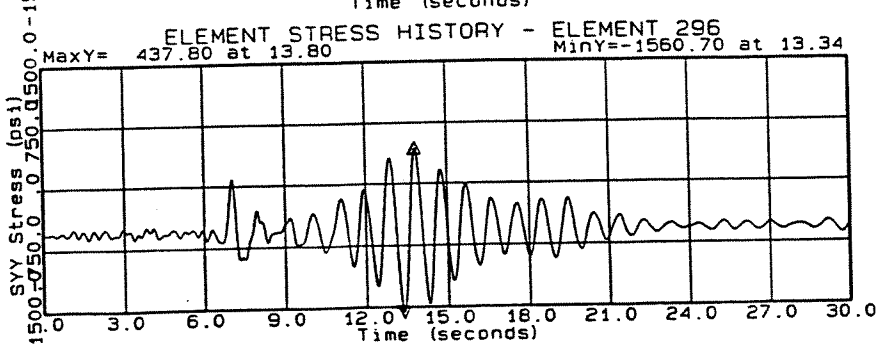
Geom file=sh07s4.elem





Geom file=sh07s4.elem



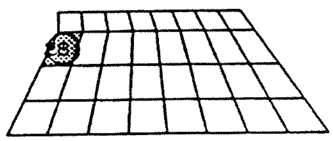


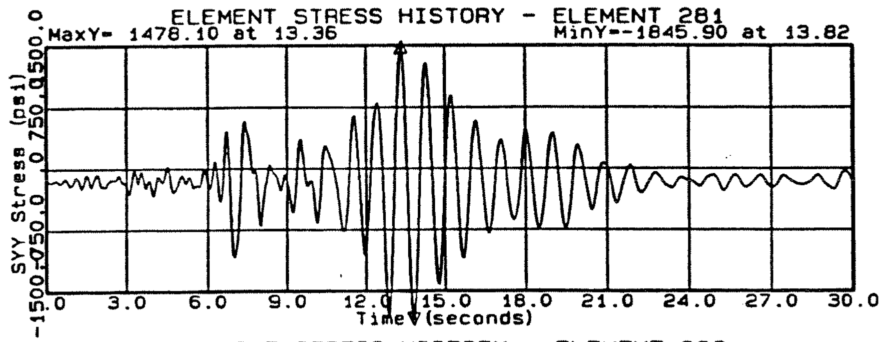
Input=streshist5.p2p. Created 18-Feb-98 10:49:34

Figure 21

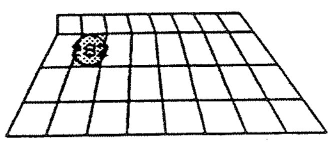
SHASTA DAM RAISE - EL.1280.0 - 0.70: 1

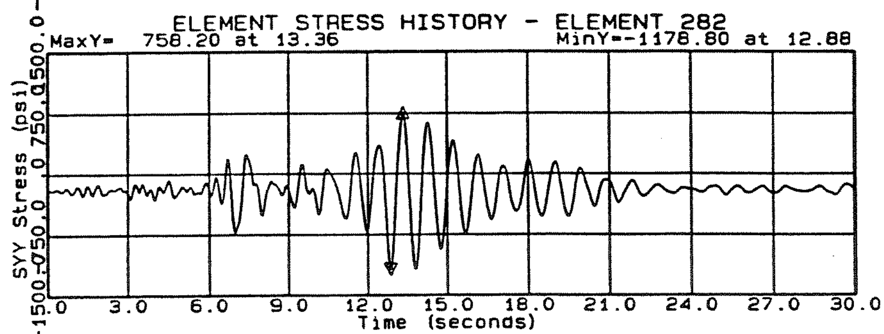
Geom file=sh07s4.elem



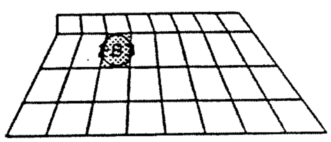


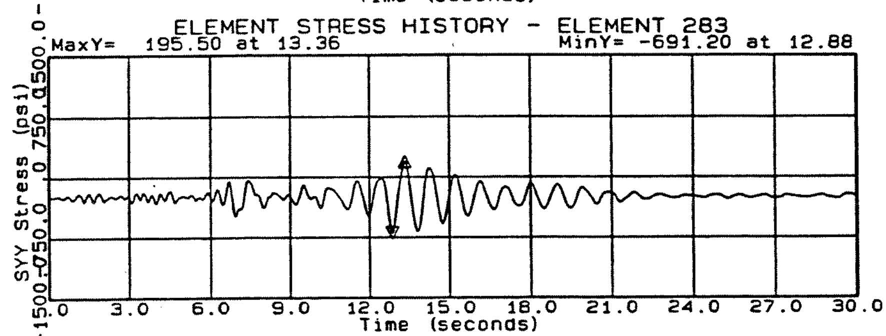
Geom file=sh07s4.elem



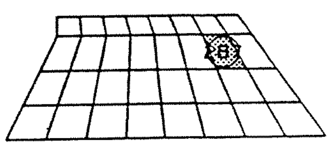


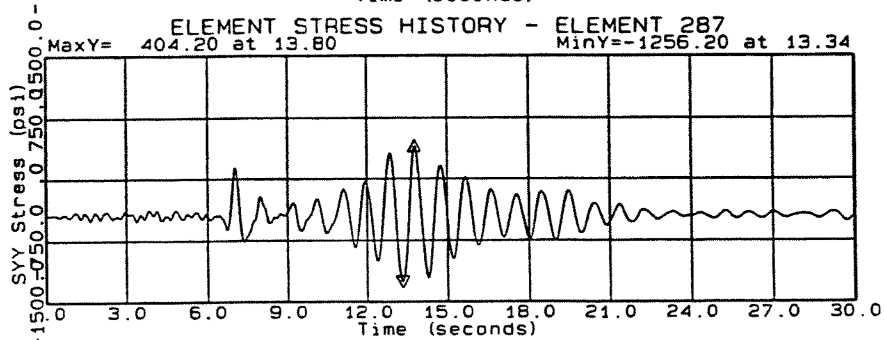
Geom file=sh07s4.elem



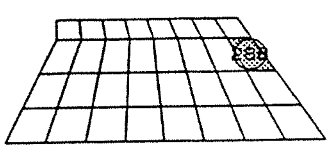


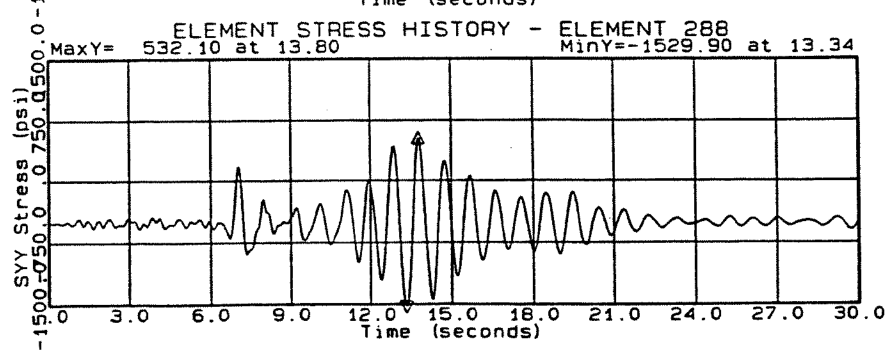
Geom file=sh07s4.elem





Geom file=sh07s4.elem

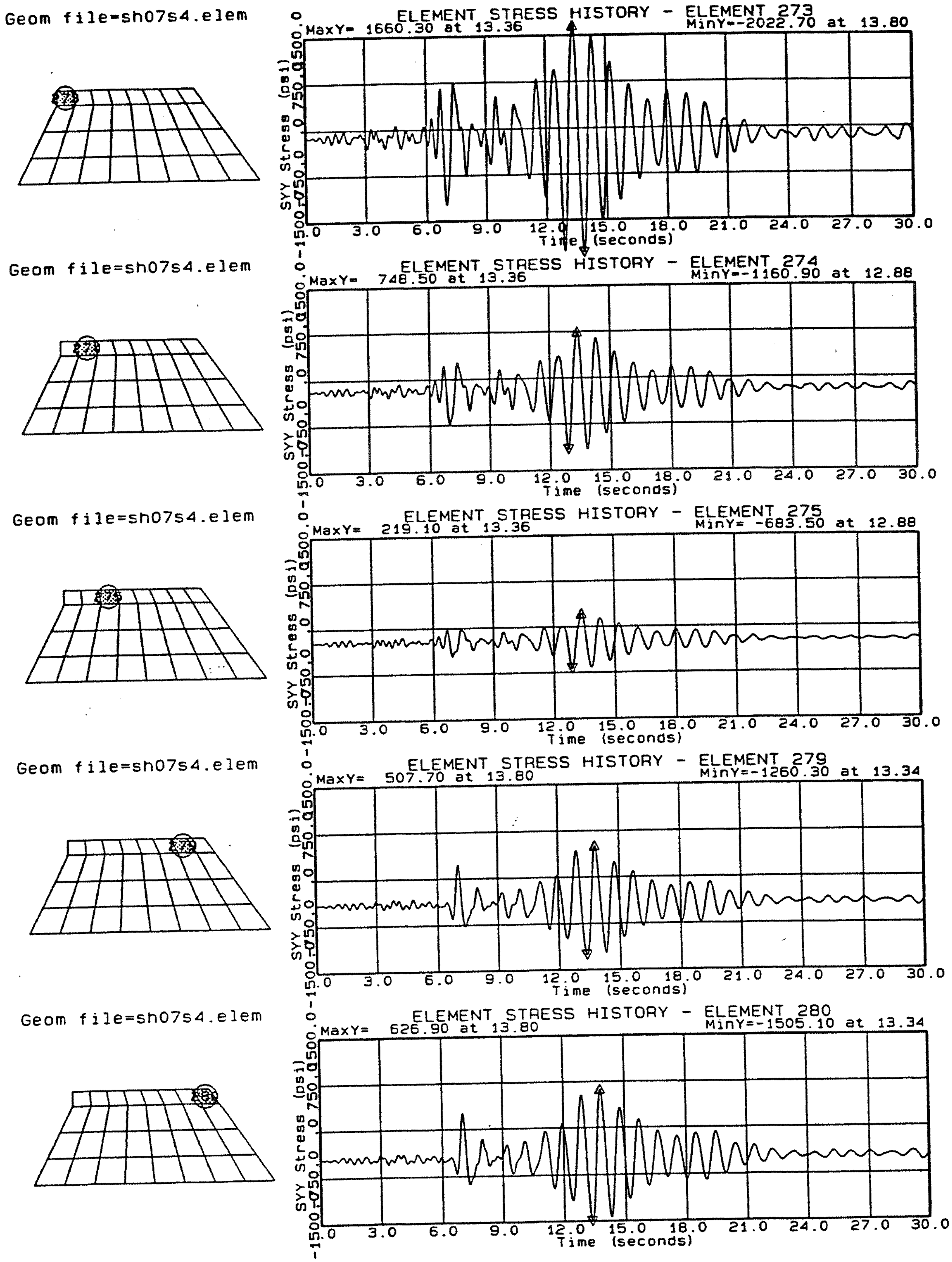




Input=streshist5.p2p, Created 18-Feb-98 14:56:51

Figure 22

SHASTA DAM RAISE - EL.1280.0 - 0.70: 1

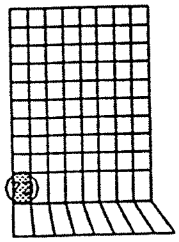


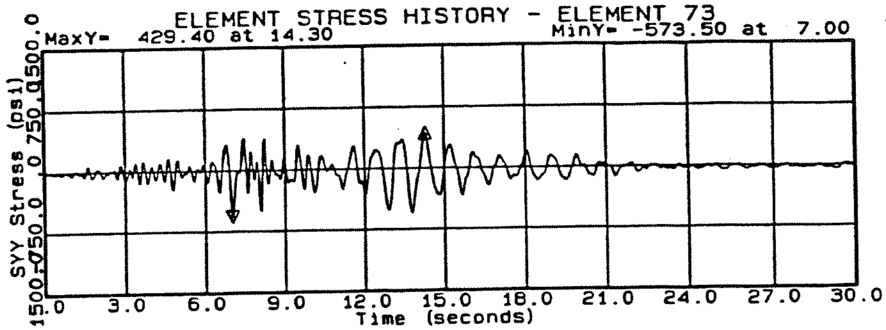
Input=streshist5.p2p. Created 18-Feb-98 14:51:07

Figure 23

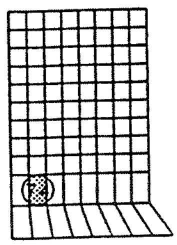
SHASTA DAM RAISE - EL.1280.0 - 0.70: 1

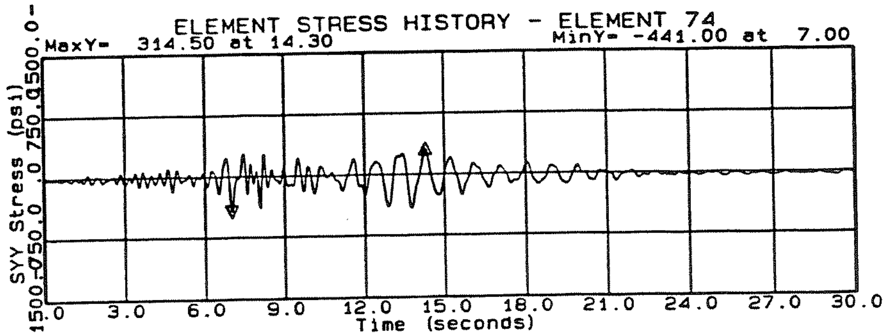
Geom file=sh07s4.elem



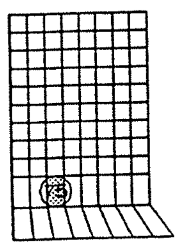


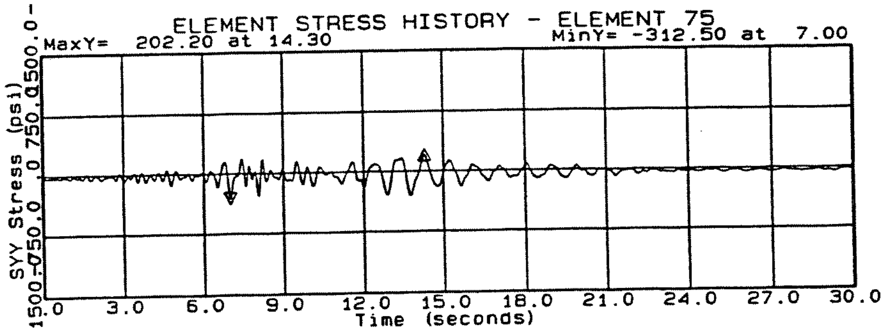
Geom file=sh07s4.elem



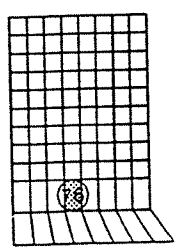


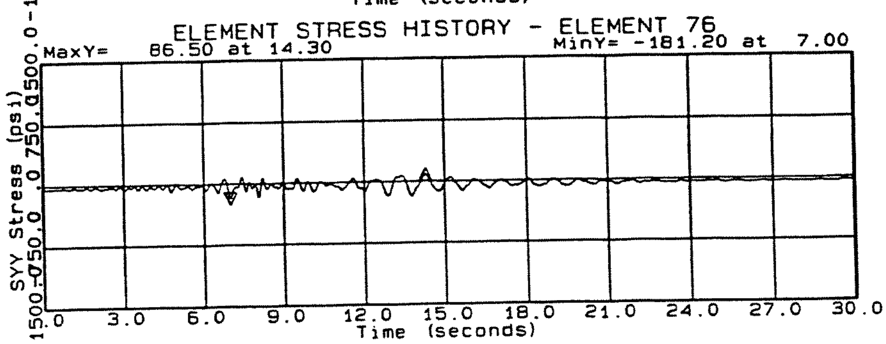
Geom file=sh07s4.elem



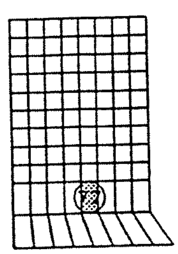


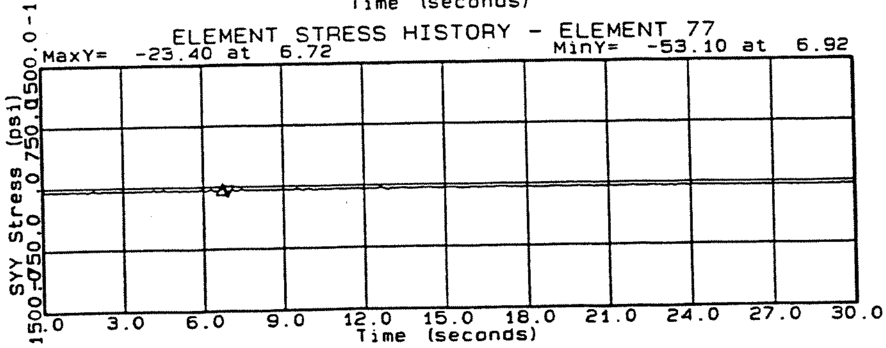
Geom file=sh07s4.elem





Geom file=sh07s4.elem



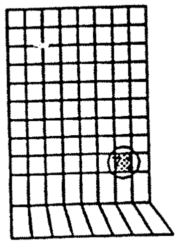


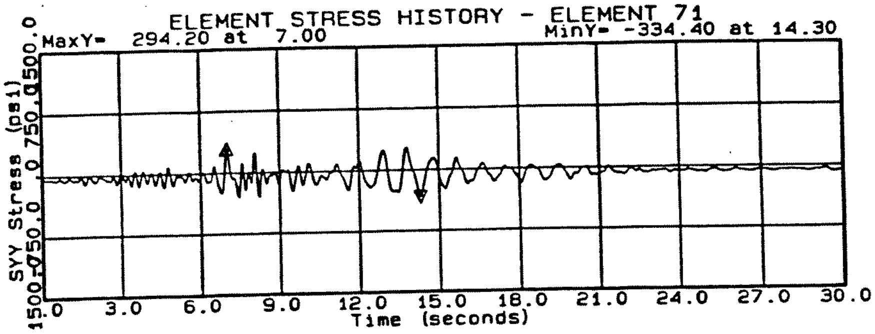
Input=streshist5.p2p. Created 8-Feb-98 12:17:35

Figure 2

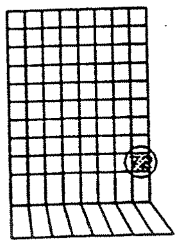
SHASTA DAM RAISE - EL.1280.0 - 0.70: 1

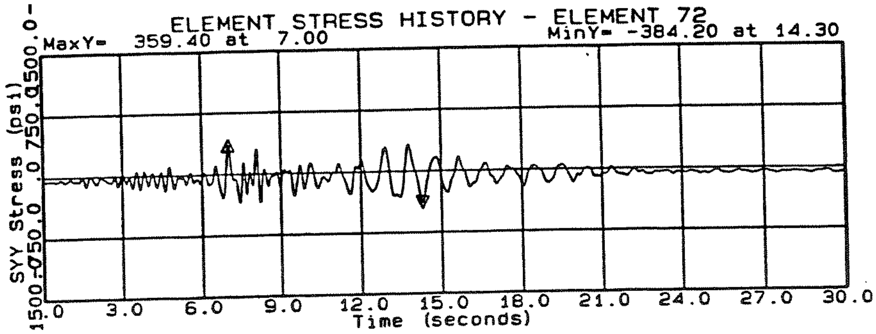
Geom file=sh07s4.elem



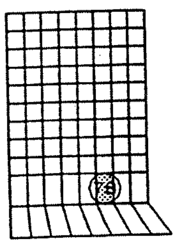


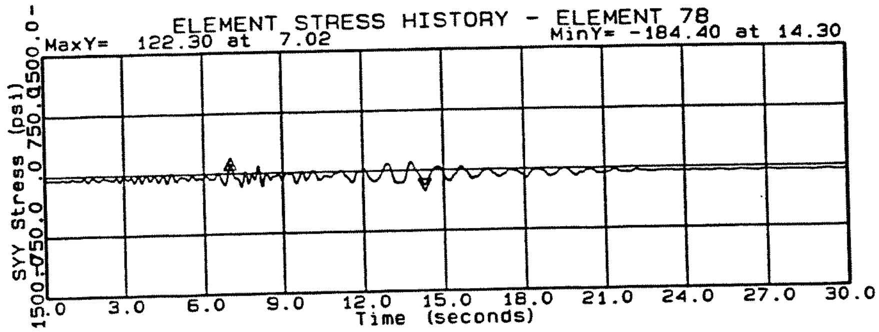
Geom file=sh07s4.elem



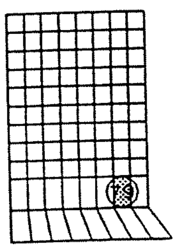


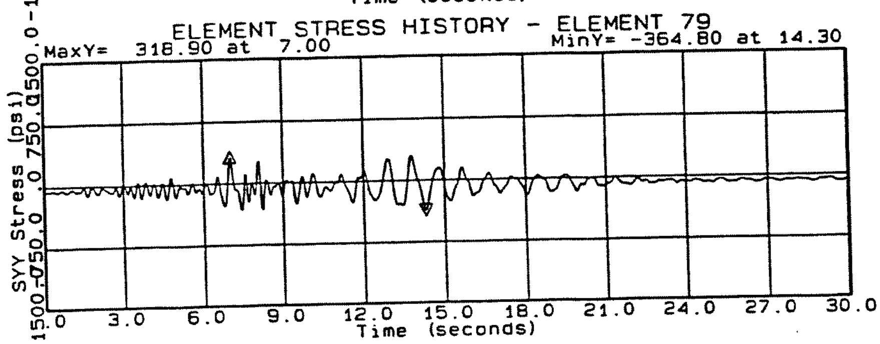
Geom file=sh07s4.elem



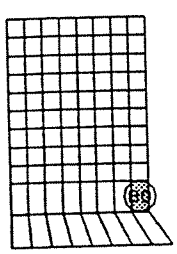


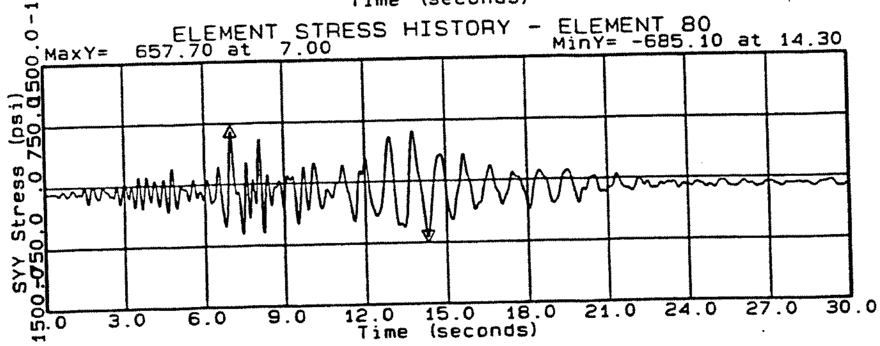
Geom file=sh07s4.elem





Geom file=sh07s4.elem





Input=streshist5.p2p. Created 8-Feb-98 11:48:26

Figure 25

SHASTA DAM RAISE - El. 1280.0 - 0.70: 1

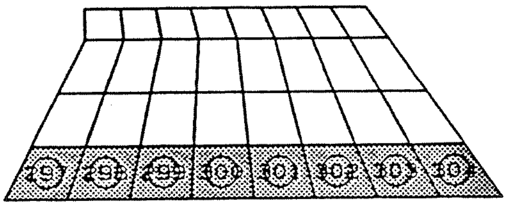
SLIDING PROPERTIES

ELEM	AREA in2	COHb psi	ANGb degree	COHu psi	ANGu degree	UPLIFT psi
297	903.00	300.0	45.00	90.0	45.00	96.49
298	903.00	300.0	45.00	90.0	45.00	82.89
299	903.00	300.0	45.00	90.0	45.00	69.29
300	903.00	300.0	45.00	90.0	45.00	55.69
301	903.00	300.0	45.00	90.0	45.00	42.09
302	903.00	300.0	45.00	90.0	45.00	28.50
303	903.00	300.0	45.00	90.0	45.00	14.90
304	903.00	300.0	45.00	90.0	45.00	1.30

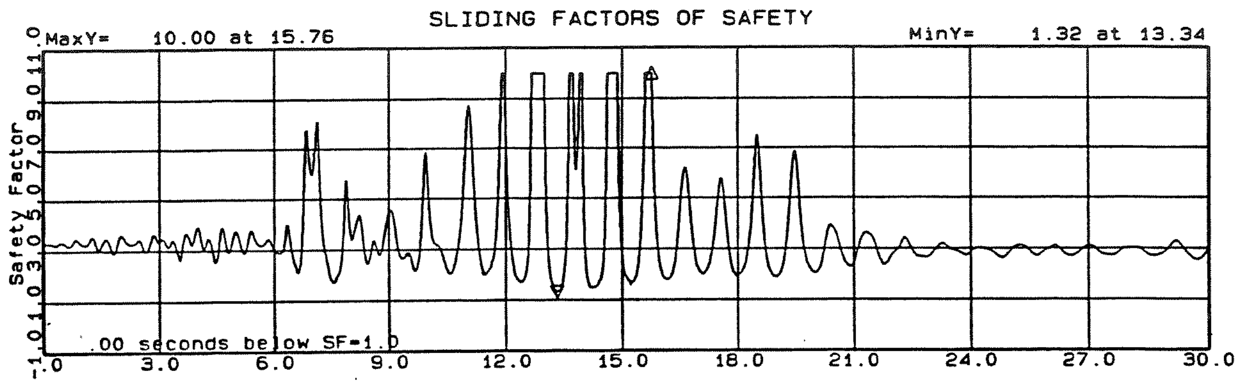
Tension limit = 200.0

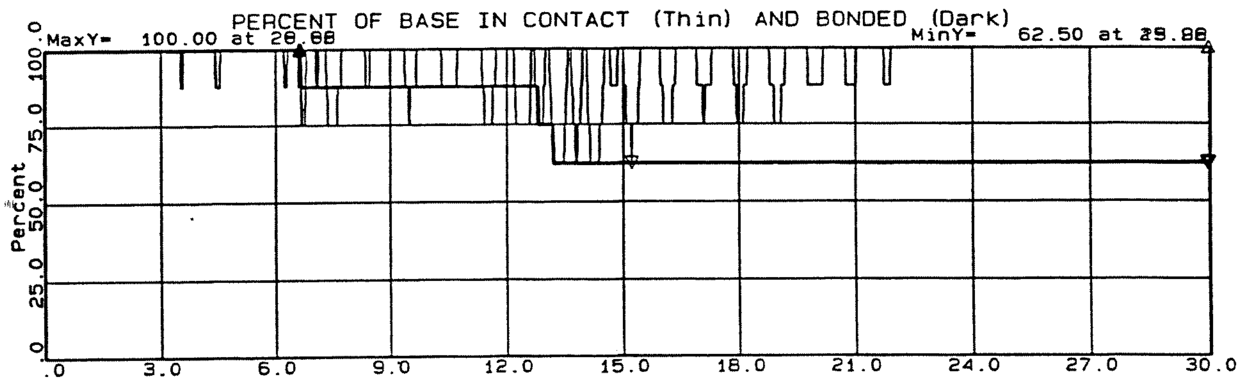
UPLIFT DATA

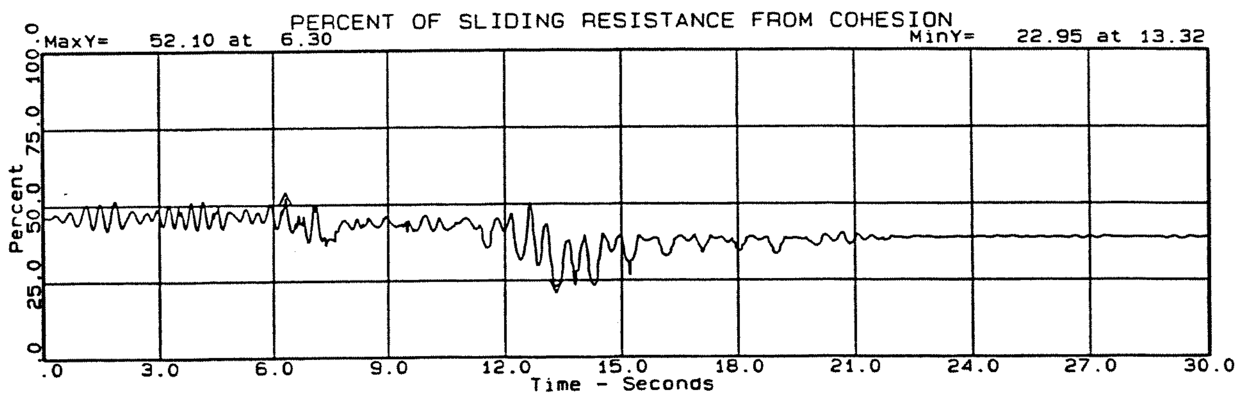
H1= 8820.0 H2= .0 H3= 2488.2 H4=
XDRN= 180.0 XCRK= -1050.0 DE= .7 BASE= 7224
REL= 15360.0 BEL= 6540.0 TWEL= 6120.0 GEL=



SLIDE PLANE







Input=pltslide.p2p, Created 9-Feb-98 14:32:21

Figure 26

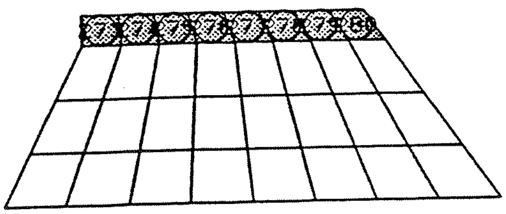
SHASTA DAM RAISE - El. 1280.0 - 0.70: 1

SLIDING PROPERTIES

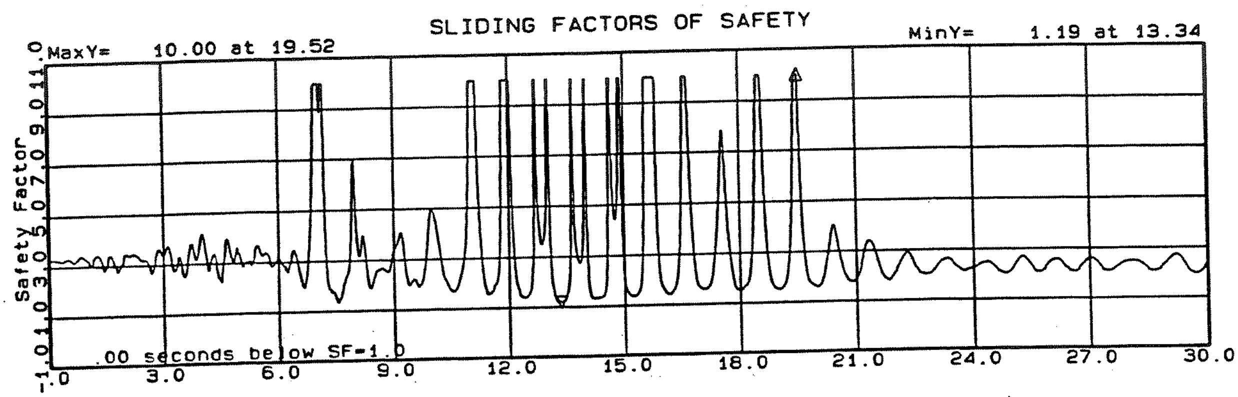
ELEM	AREA in2	COHb psi	ANGb degree	COHu psi	ANGu degree	UPLIFT psi
273	567.00	300.0	45.00	90.0	45.00	85.48
274	567.00	300.0	45.00	90.0	45.00	73.30
275	567.00	300.0	45.00	90.0	45.00	61.12
276	567.00	300.0	45.00	90.0	45.00	48.94
277	567.00	300.0	45.00	90.0	45.00	36.75
278	567.00	300.0	45.00	90.0	45.00	24.57
279	567.00	300.0	45.00	90.0	45.00	12.39
280	567.00	300.0	45.00	90.0	45.00	.21
Tension limit =			200.0			

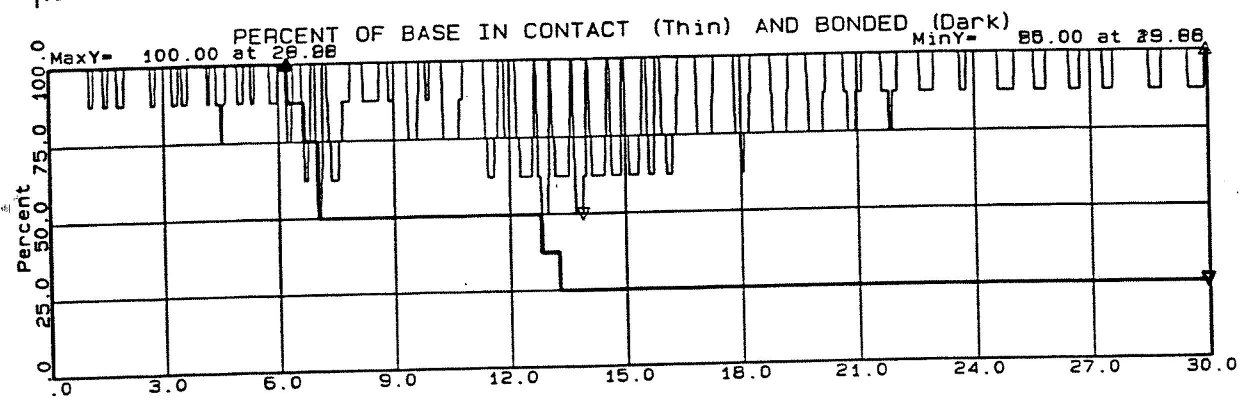
UPLIFT DATA

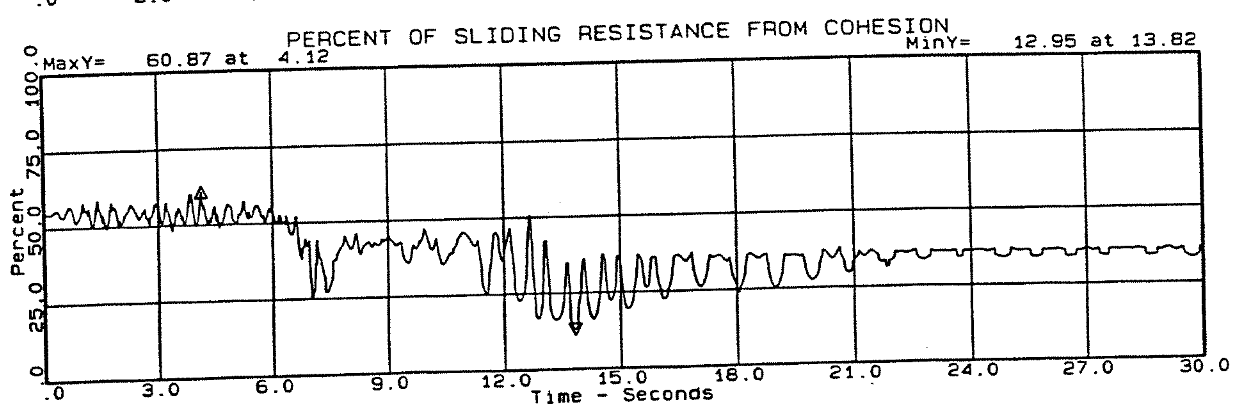
H1= 6480.0 H2= .0 H3= 2115.8 H4= .0
XDRN= 180.0 XCRK= .0 DE= .7 BASE= 4536.0
REL= 15360.0 BEL= 8880.0 TWEL= 6120.0 GEL= .0



SLIDE PLANE



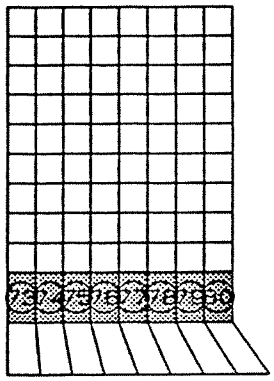




Input=pltslide.p2p, Created 10-Feb-98 08:56:11

Figure 27

SHASTA DAM RAISE - El. 1280.0 - 0.70: 1

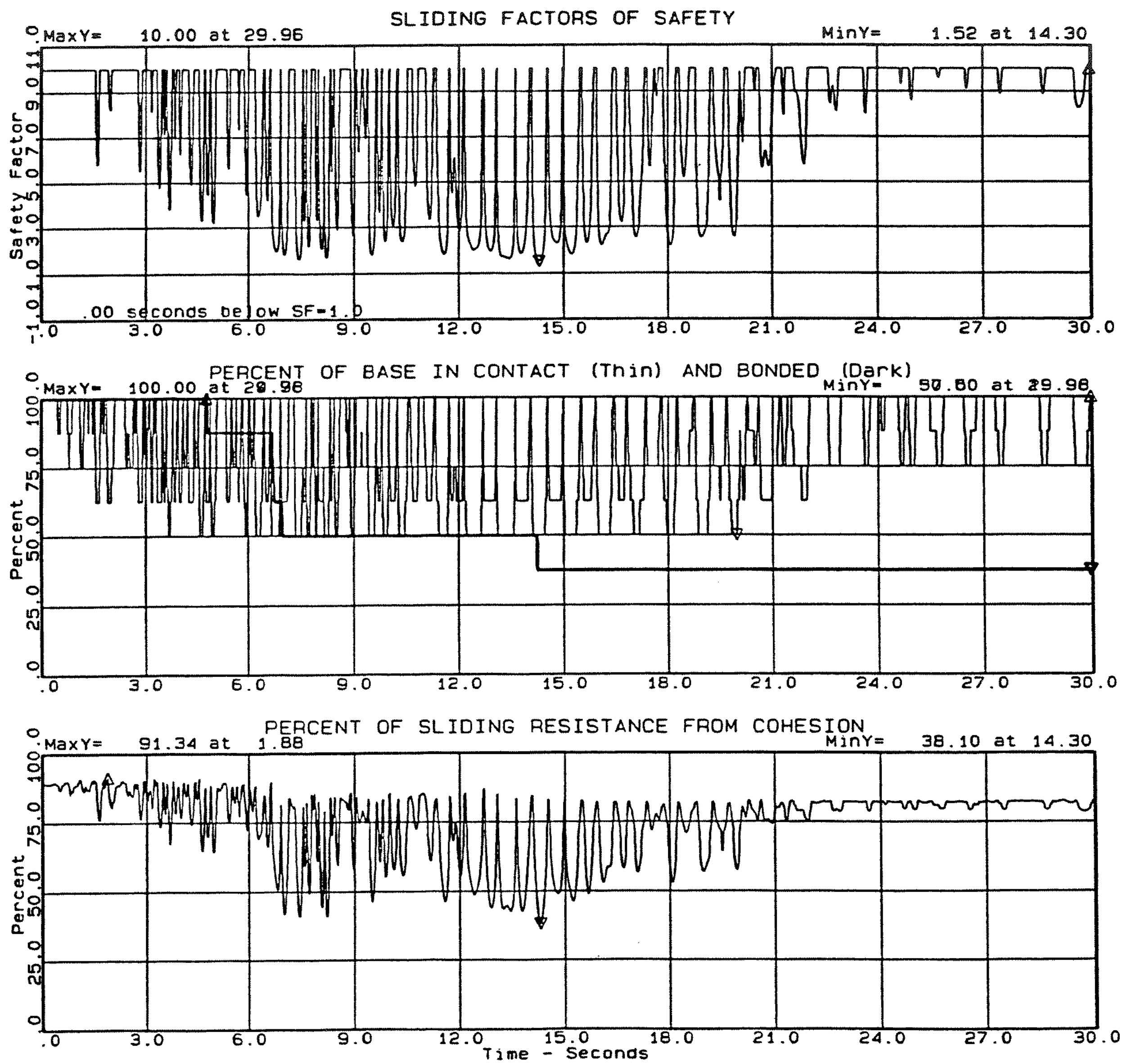


SLIDING PROPERTIES

ELEM	AREA in2	COHb psi	ANGb degree	COHu psi	ANGu degree	UPLIFT psi
73	45.00	300.0	45.00	90.0	45.00	13.20
74	45.00	300.0	45.00	90.0	45.00	11.06
75	45.00	300.0	45.00	90.0	45.00	8.93
76	45.00	300.0	45.00	90.0	45.00	6.79
77	45.00	300.0	45.00	90.0	45.00	4.66
78	45.00	300.0	45.00	90.0	45.00	2.52
79	45.00	300.0	45.00	90.0	45.00	.38
80	45.00	300.0	45.00	90.0	45.00	-1.75
Tension limit =			200.0			

UPLIFT DATA

H1=	473.1	H2=	.0	H3=	80.4	H4=	
XDRN=	180.0	XCRK=	.0	DE=	.7	BASE=	36(
REL=	15360.0	BEL=	14886.9	TWEL=	6120.0	GEL=	

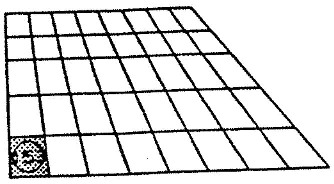


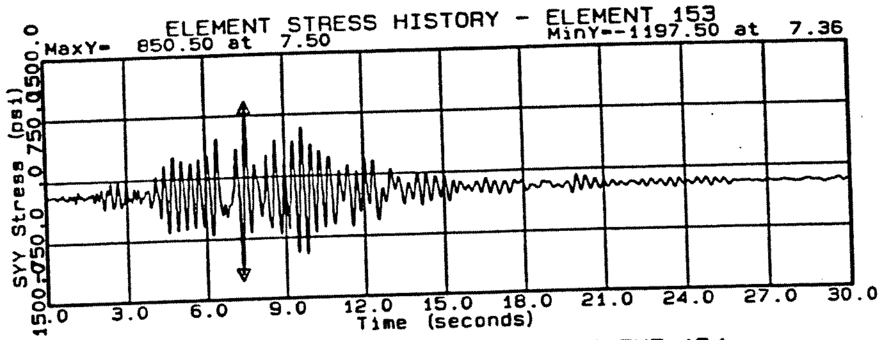
Input=pltslide.p2p, Created 10-Feb-98 08:37:15

Figure 28

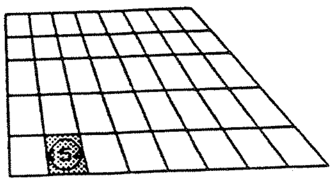
SHASTA DAM 300ft RCC - 0.80: 1

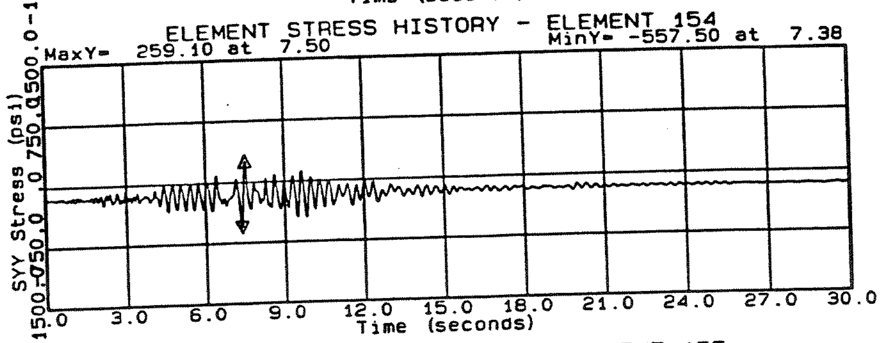
Geom file=shrcc.elem





Geom file=shrcc.elem





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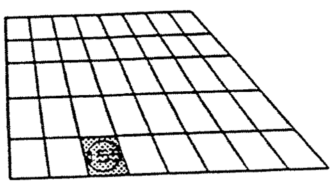

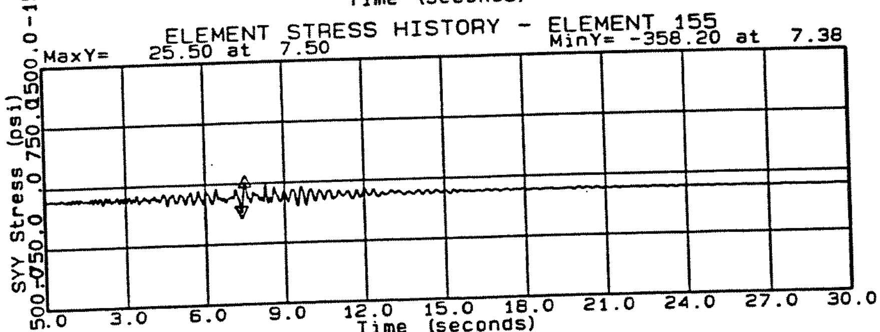

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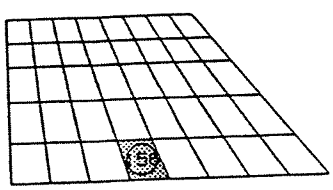

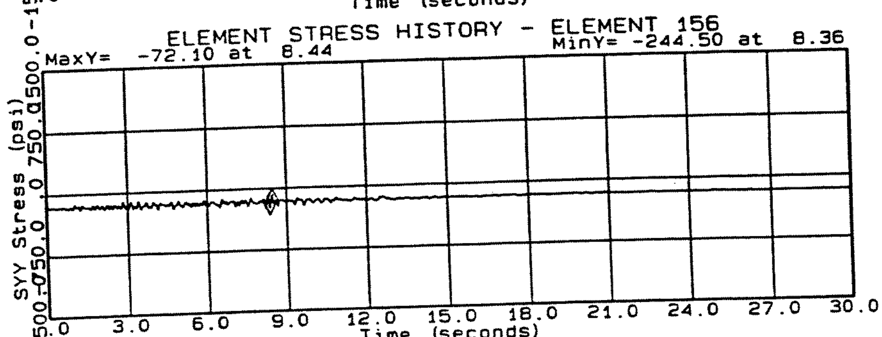

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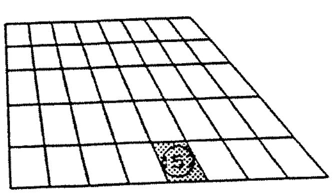
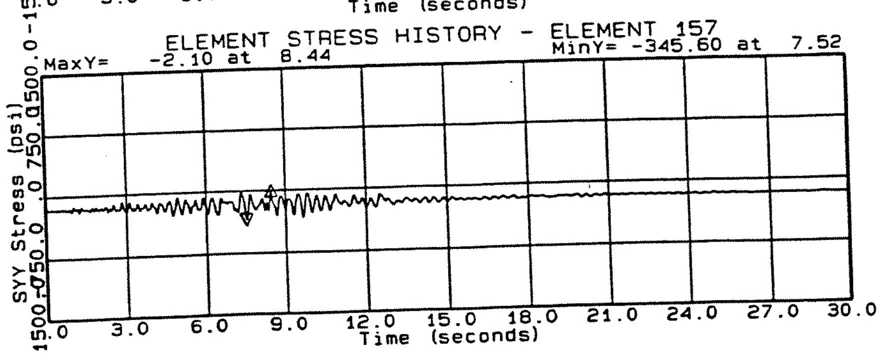
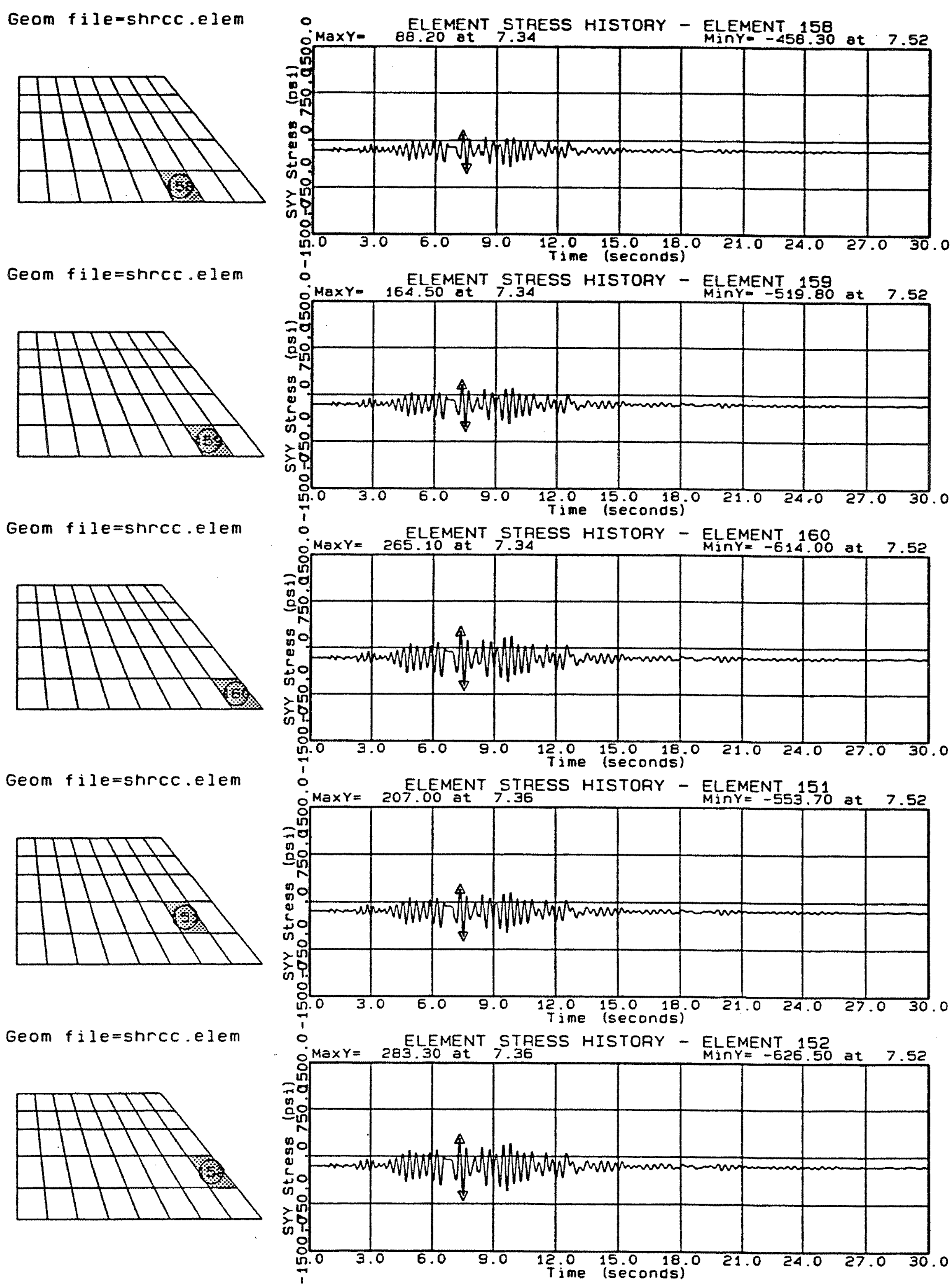




Input=streshist5.p2p. Created 8-Feb-98 12:08:30

Figure 29

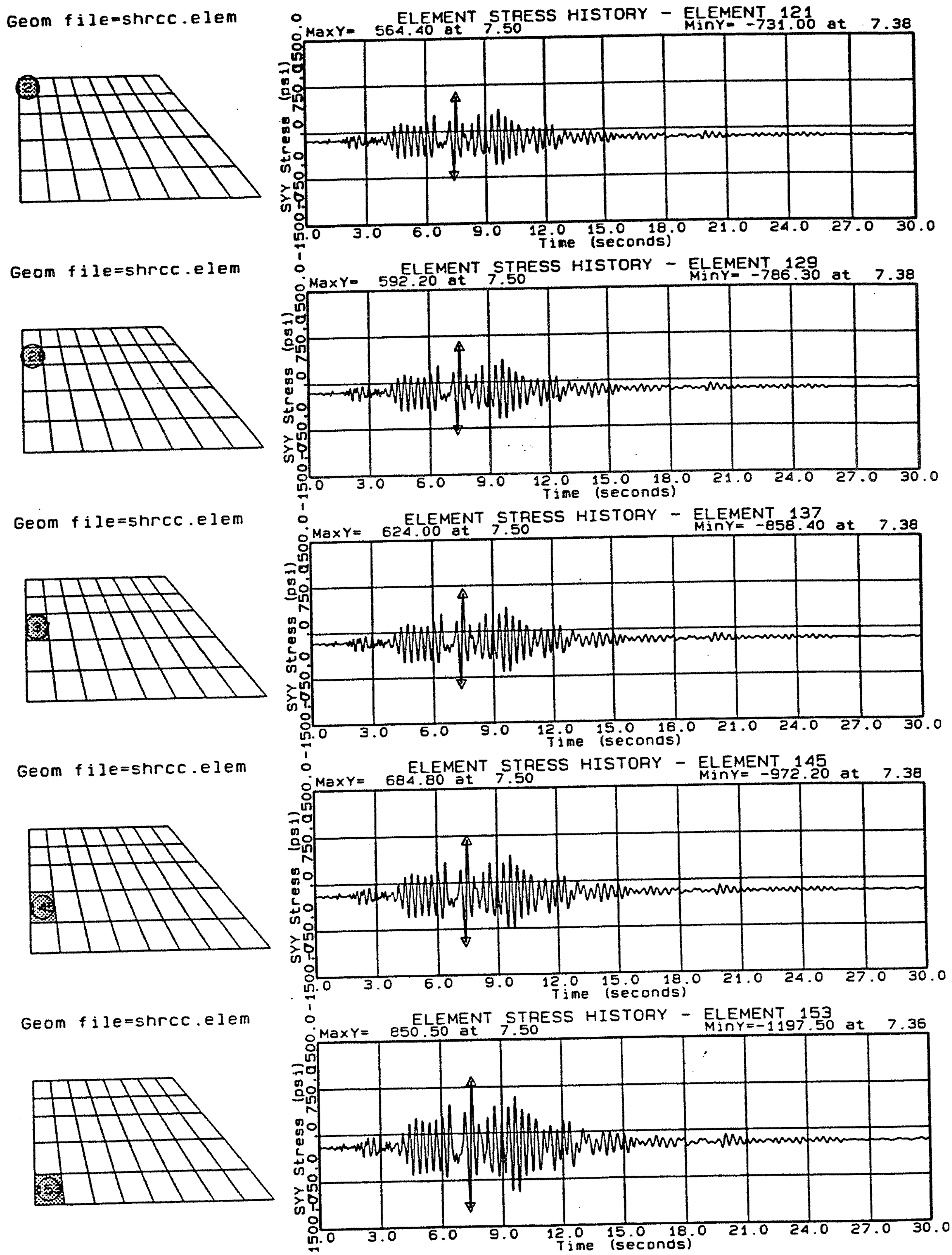
SHASTA DAM 300ft RCC - 0.80: 1



Input=streshist5.p2p. Created 9-Feb-98 11:19:13

Figure 30

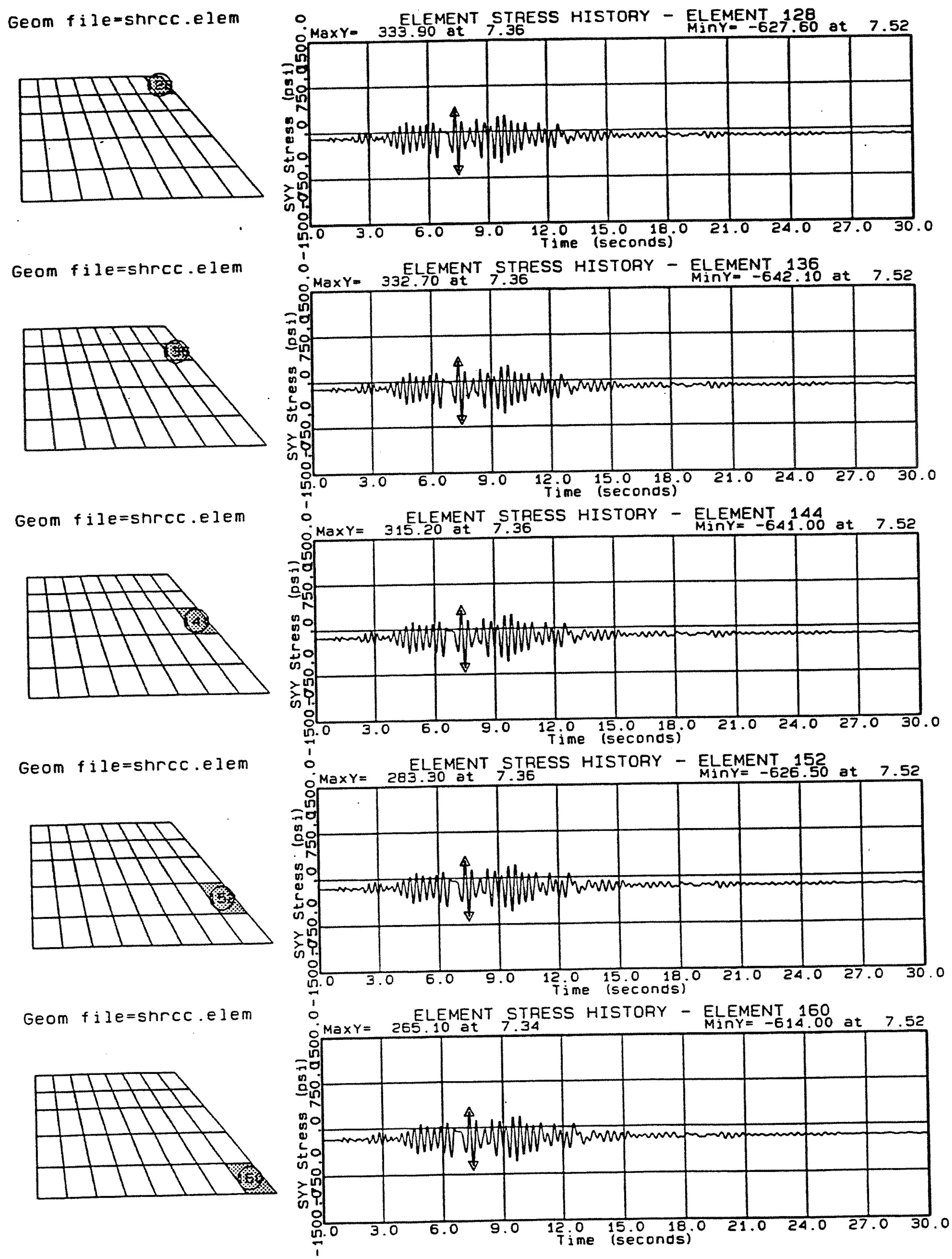
SHASTA DAM 300ft RCC - 0.80: 1



Input=streshist5.p2p, Created 19-Feb-98 14:21:39

Figure 31

SHASTA DAM 300ft RCC - 0.80: 1

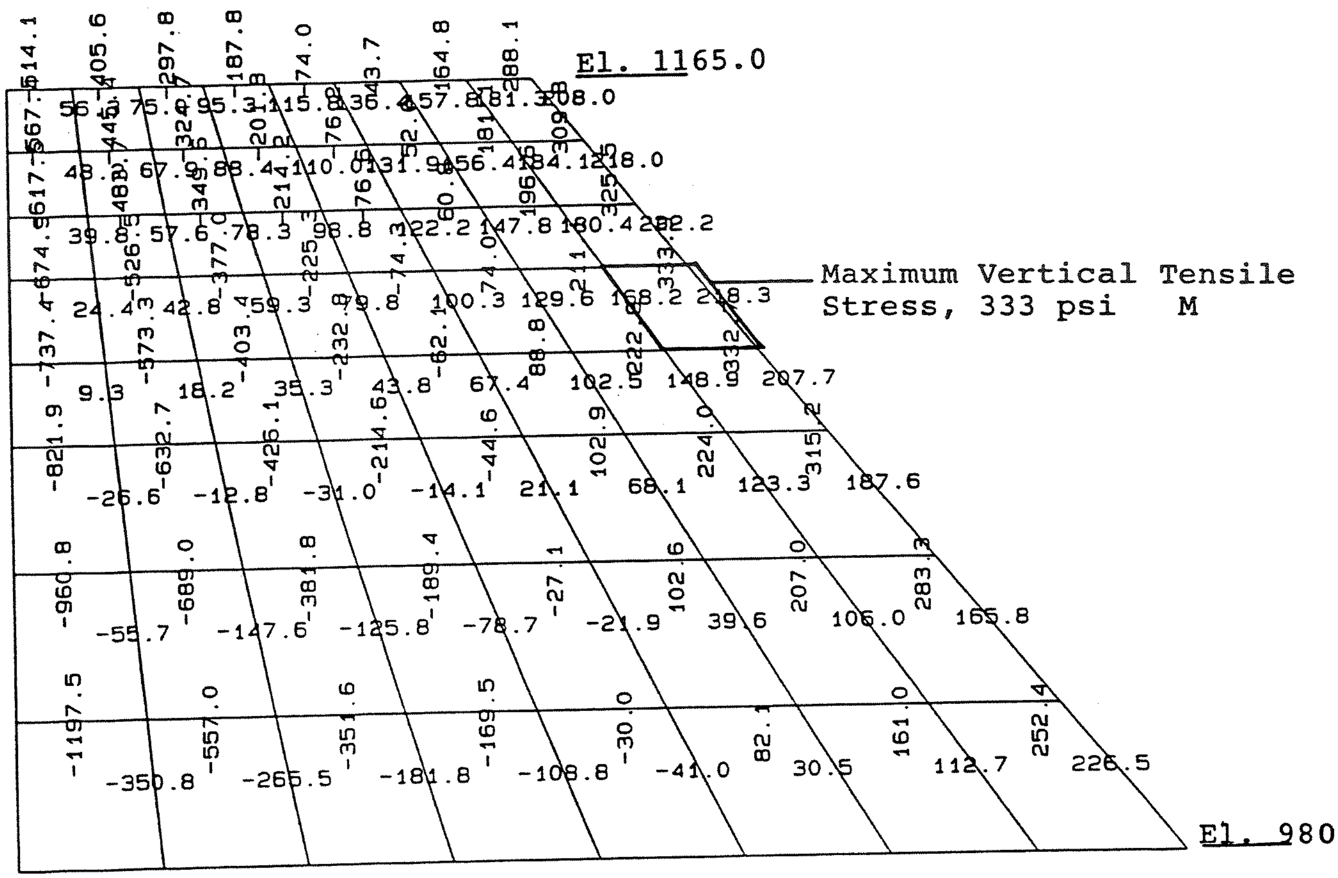


Input=streshist5.p2p. Created 19-Feb-98 14:13:54

Figure 32

SHASTA DAM 300ft High RCC - 0.80: 1

Geom file=shrcc.elem
Stress file=sheqbsd.stress
Plotting: Sxx stresses at time 7.360 seconds
Plotting: Syy stresses at time 7.360 seconds



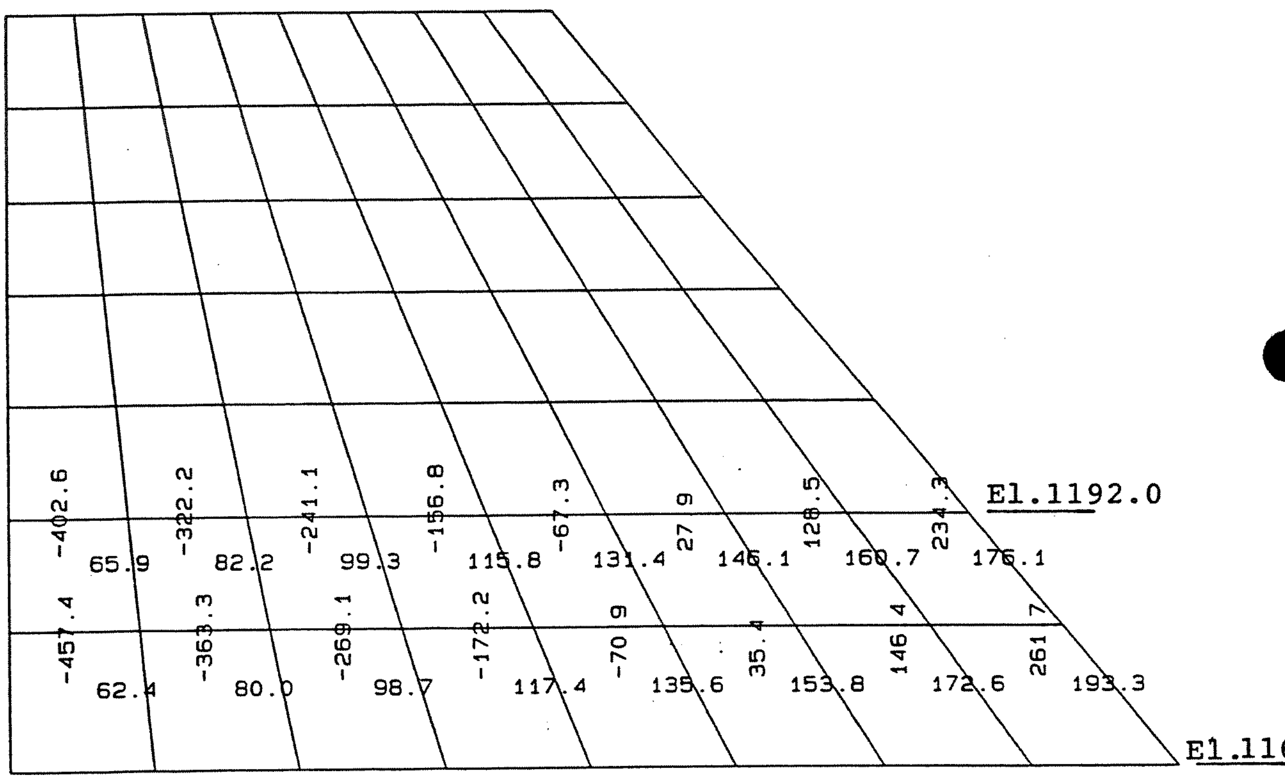
Horizontal and Vertical Stress at Time 7.36

Input=plt2df8.p2p, Created 20-Feb-98 07:57:40

Figure 33a

SHASTA DAM 300ft High RCC - 0.80: 1

Geom file=shrcc.elem
Stress file=sheqbsd.stress
Plotting: Sxx stresses at time 7.360 seconds
Plotting: Syy stresses at time 7.360 seconds



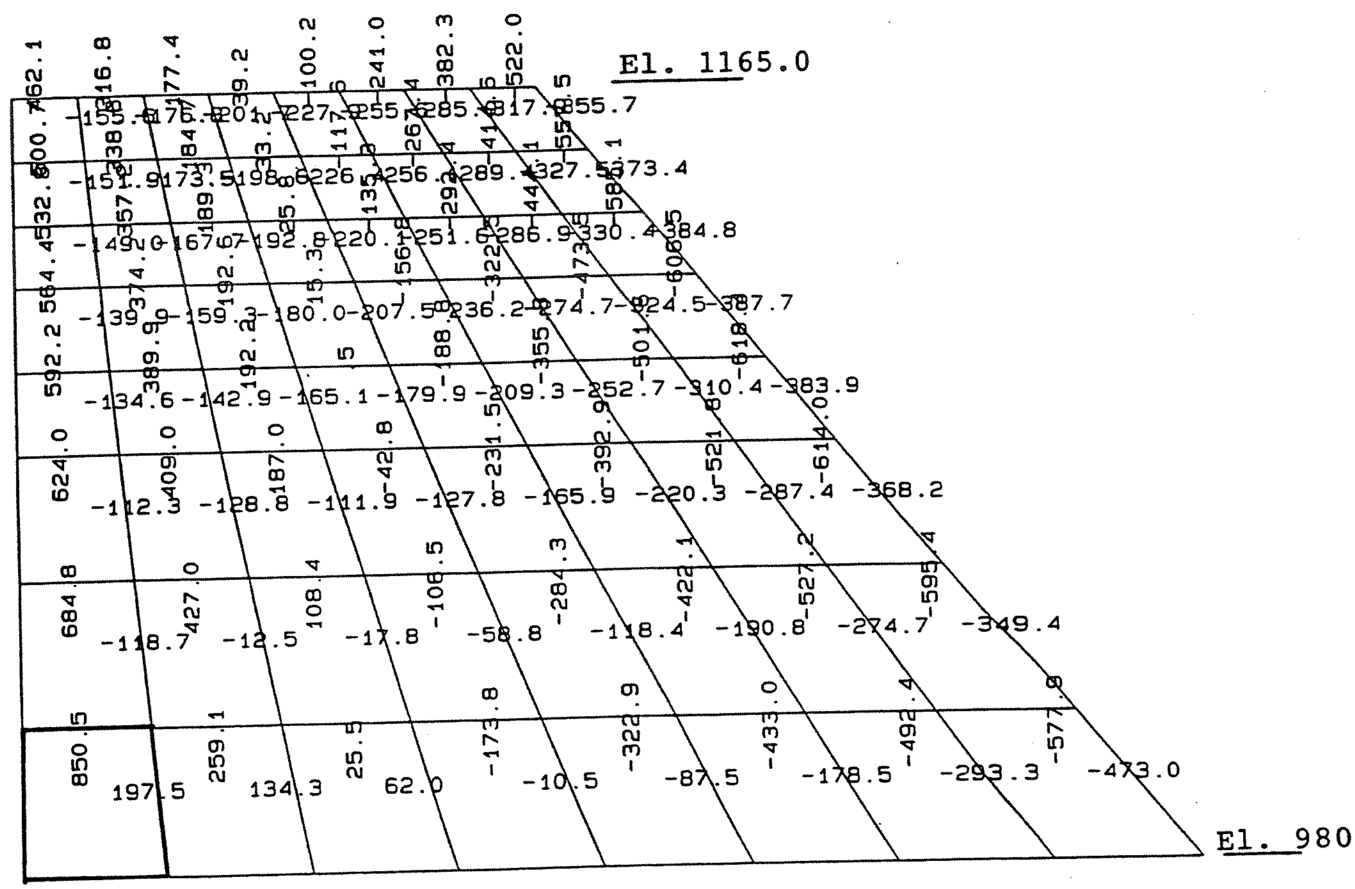
Horizontal and Vertical Stress at Time 7.36

Input=plt2df8.p2p, Created 20-Feb-98 08:01:53

Figure 33b

SHASTA DAM 300ft High RCC - 0.80: 1

Geom file=shrcc.elem
Stress file=sheqbsd.stress
Plotting: Sxx stresses at time 7.500 seconds
Plotting: Syy stresses at time 7.500 seconds

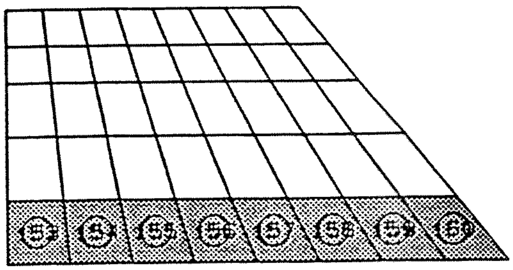


Horizontal and Vertical Stress at Time 7.50

Input=plt2df8.p2p. Created 20-Feb-98 10:06:08

Figure 34

SHASTA DAM 300ft RCC - 0.80: 1



SLIDE PLANE

SLIDING PROPERTIES

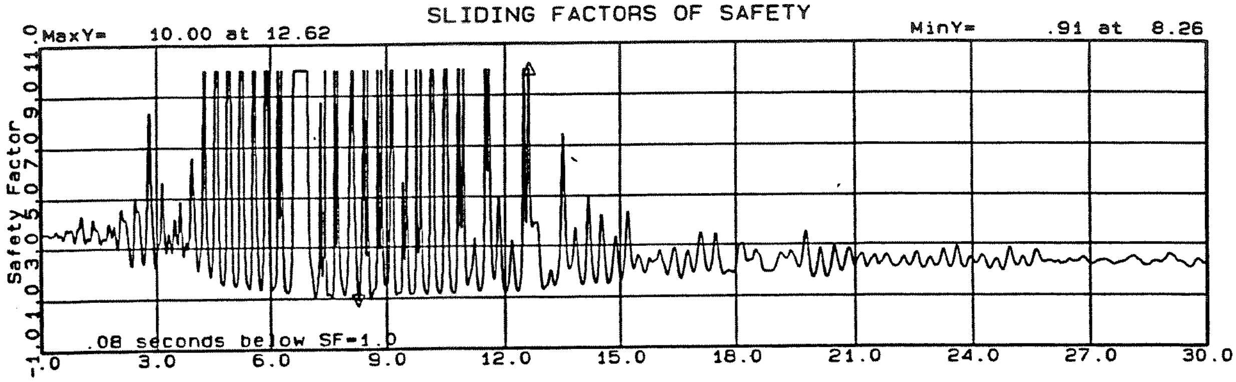
ELEM	AREA in2	COHb psi	ANGb degree	COHu psi	ANGu degree	UPLIFT psi
153	384.00	100.0	45.00	.0	45.00	44.18
154	384.00	100.0	45.00	.0	45.00	37.21
155	384.00	100.0	45.00	.0	45.00	30.24
156	384.00	100.0	45.00	.0	45.00	23.27
157	384.00	100.0	45.00	.0	45.00	16.30
158	384.00	100.0	45.00	.0	45.00	9.33
159	384.00	100.0	45.00	.0	45.00	2.36
160	384.00	100.0	45.00	.0	45.00	-4.61

Tension limit = .0

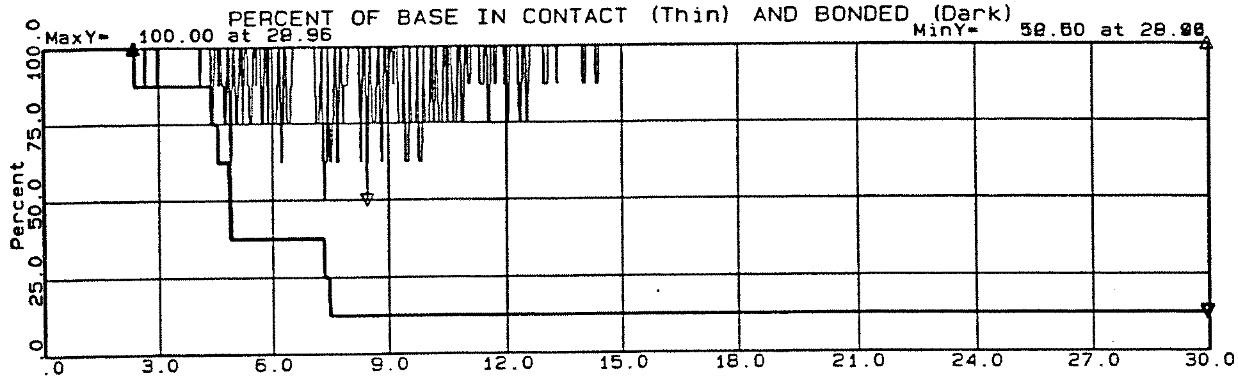
UPLIFT DATA

H1=	3390.0	H2=	.0	H3=	764.7	H4=	
XDRN=	300.0	XCRK=	.0	DE=	.8	BASE=	307
REL=	3600.0	BEL=	210.0	TWEL=	.0	GEL=	

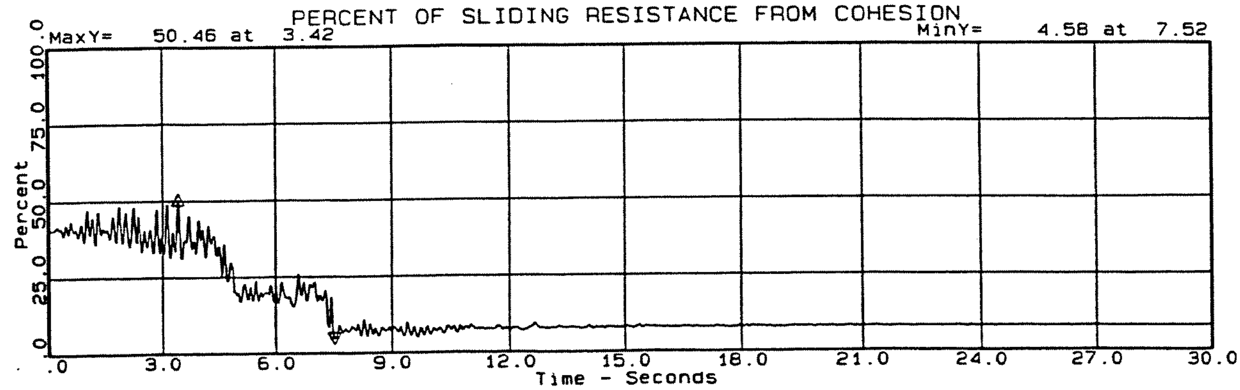
SLIDING FACTORS OF SAFETY



PERCENT OF BASE IN CONTACT (Thin) AND BONDED (Dark)



PERCENT OF SLIDING RESISTANCE FROM COHESION



Input=pltslide.p2p. Created 10-Feb-98 08:57:51

Figure 3!

Memorandum

To: Tom Hepler, D-8130

From: Bitsy Cohen, D-8130 Bitsy Cohen

Subject: Hydraulic Analysis of Shasta Dam Stilling Basin with the Proposed Raise of the Top of the Dam to Elevation 1280.0, Central Valley Project, CA

This memorandum contains the results of a hydraulic analysis of the stilling basin at Shasta Dam with the spillway crest at elevation 1244.0, the top of dam at elevation 1280, and a design maximum flow of 250,000 ft^3/s (see figure 1 for general layout). The specific questions and responses that are contained in this memorandum provide information for those conditions. In a feasibility design, various flow rates should be investigated to ensure all conditions are satisfactory, including the worst condition (which may not be 250,000 ft^3/s).

1. Compute water surface profile for 250,000 ft^3/s flow down 0.7:1 sloping face, from spillway crest at elevation 1244 to stilling basin. Determine flow depths for sizing training walls (assuming 30 foot wall heights).

See figure 2 for a plot of the depth of flow, figure 3 for a plot of the water surface profile, and figure 4 for the water surface profile for just the stilling basin.

The walls need to be a minimum of 32.5 feet high at the gates (28 foot depth plus 4.5 feet for freeboard). As the flow goes down the face of the dam, a parallel offset of 30 feet equals a vertical wall height of 52.5 feet. That represents a 5 foot decrease in wall height from the existing design; however, that is enough for a total wall height of depth of flow plus freeboard in the spillway chute. The minimum freeboard in the chute as shown is approximately 10 feet. The freeboard in the basin should be approximately 10 feet but, as shown, indicates an area of concern with insufficient freeboard if the stilling basin walls are not raised.

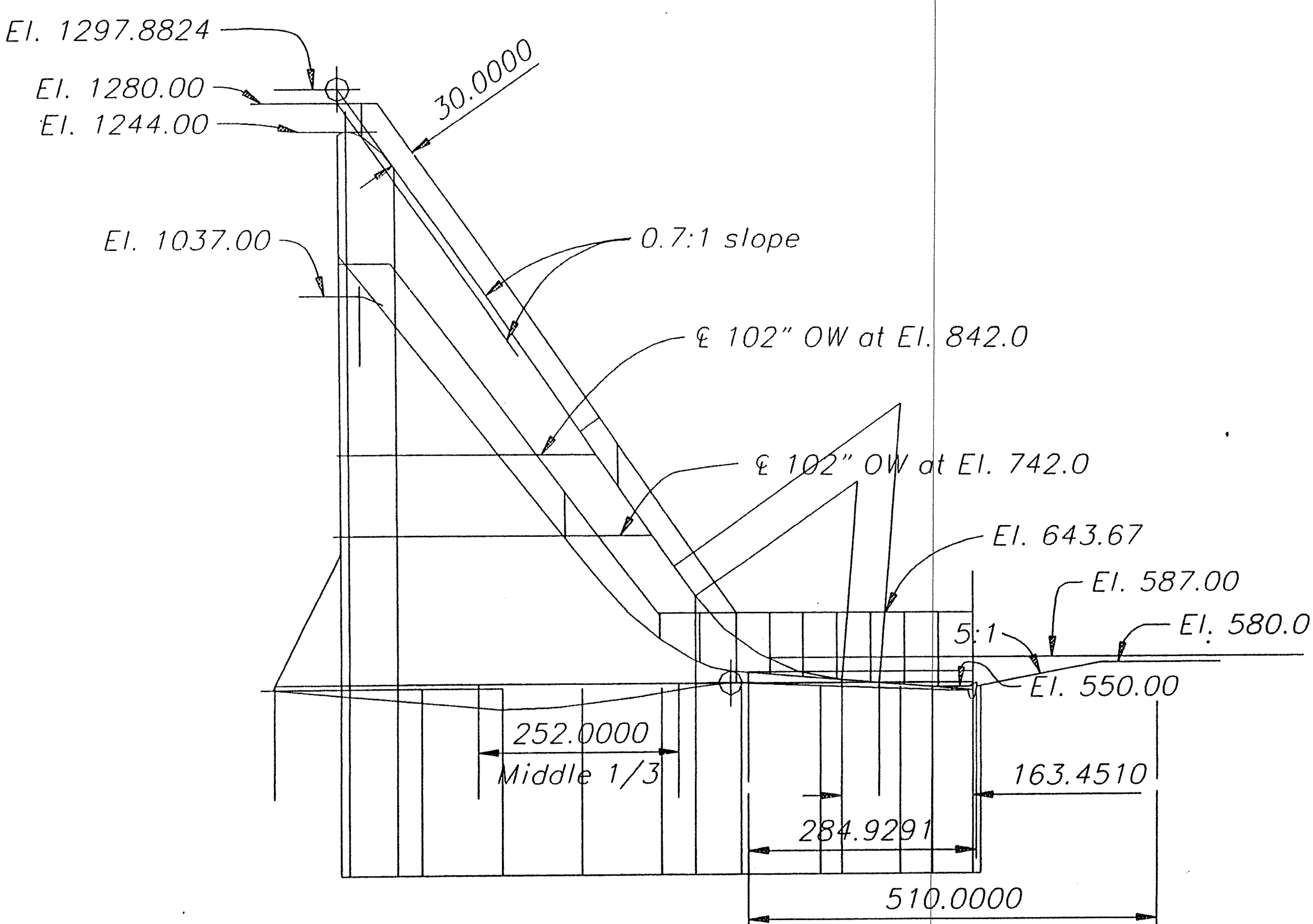


Figure 1 - Shasta Dam, General layout of raised section over existing section.

2. Evaluate cavitation potential of spillway chute. Can we assume air flow from outlets to help the situation? Air slot options?

The cavitation index goes below 0.2 (threshold for damage) before Sta 3+00, at elevation 1012 (see figures 5 and 6). This is well above the elevation of the upper tier of the outlet works (elevation 942). Therefore we would probably need to accommodate the air demand higher up on the face of the dam, certainly above the outlet works portals. The feasibility design needs to investigate the volume of air required and determine if all of the air can come from the sides in a slot or if additional air vents will need to be brought into the interior of the slot.

The outlet works will supply a portion of the air demand from flow through the upstream air vents, however this will not accomplish full aeration nor prevent significant damage. The exit portals for the outlets are in an area where the cavitation index is 0.1 or less, indicating there is high potential for damage in this area unless special precautions are taken.

3. Evaluate energy dissipation in stilling basin - 12:1 sloping apron, from about elevation 570 to 550, with blocks and/or dentated sill, and an overall length of about 340 feet. Any major changes required to dissipate energy?

The tailwater for 250,000 ft^3/s is approximately elevation 632 (drawing 214-D-704, Shasta Dam, Area, Capacity and Discharge Curves, Revised 1944). This is deep enough to force a hydraulic jump for the existing basin, however, this doesn't appear to be deep enough to force a hydraulic jump for the raised Shasta Dam with smooth spillway chute, or the jump will be very rough. In feasibility design, the tailwater curve should be revisited and validated.

Figure 7 shows the energy grade lines for this structure. The typical design of a type V sloping floor stilling basin would indicate that approximately a 500 foot basin is required for an effective stilling basin over the full range of discharges. The existing Shasta Dam stilling basin has approximately 392 foot long stilling basin walls, and the 12:1 sloping floor is approximately 304 feet long. The required radius of the curve to direct flow into the stilling basin for the enlarged dam is on the order of 250 to 300 feet. This radius, plus the additional thickness of the dam overlay, encroaches into the stilling basin by 50 to 100 feet, in effect losing approximately 1/3 of the existing basin. The basin required for a Type V, sloping apron basin for the additional height and discharge, requires approximately a 525 foot long basin for the raised dam. The basin, as designed, is approximately 300 feet long. This indicates that the basin was designed for a smaller discharge, hence the overall length was decreased. With the loss of 1/3 of the basin length due to the dam enlargement, there would need to be an additional length of basin required to preserve the exisitng energy dissipation capacity.

Another critical point for cavitation is at Sta. 7+27, where the curvature for the transition reaches the basin floor and the index is 0.07. At that location, the floor is approximately 7-0 feet thick and there is only 117 feet to the downstream end of the stilling basin. There would be damage in this area.

A stilling basin length of 117 feet is inadequate to dissipate the energy of the design discharge (250,000 ft^3/s), and the cavitation indices are lower than for the existing design indicating that there is a greater likelihood of having cavitation damage in a thinner floor section (7 feet versus 15 feet). There would most likely be cavitation erosion, and with a "hole" developed from cavitation, the headward migration and undercutting of the dam structure would begin.

The top of the spillway basin walls are at elevation 643.67. The walls of the stilling basin will probably need to be raised because there is less freeboard available, and if the downstream tailwater rises by approximately 10 feet, that alone may cause overtopping of the walls.

A quick check of the Stream Power for erosion was performed using data from the 1993 supplemental MDA memorandum. The Erodibility Index of 224 to 22,800 from that evaluation was used. A new stream power based on the discharge (250,000 ft^3/s) and velocity (170 ft/s) at the beginning of the stilling basin prior to energy dissipation by the hydraulic jump indicated a Stream Power index of 93,168 to 95,858 Kw/m. When plotted on the appropriate chart (refer to SD-MDA-DM-3110-93-1, dated September 30, 1993), the result is the discharge is in an area of the chart indicating there is an erosion potential. The concrete thickness of 5 to 7 feet will not withstand damage for long and there would be erosion if the stilling basin is not extended and thickened.

The concept of using steps on the downstream face of the 0.7:1 slope was briefly investigated. Conversation with Hydraulics lab personnel indicated that there have been no tests on the effectiveness of steps in conjunction with radial gate operation, as up until now the crests have all been ungated. The largest unit discharge for step spillways is approximately 350 $ft^3/s/lf$, and Reclamation experience with Upper Stillwater Dam is a unit discharge of 125 $ft^3/s/lf$. The use of large steps to dissipate energy would be effective for energy reduction at the higher discharges, but may be hydraulically inappropriate at the lower more frequent operational flows.

The length where the greatest amount of energy is dissipated, occurs in approximately the upstream 10 percent of the total length of the jump (see SD-MDA-DM-3110-93-1, dated September 30, 1993). The most destructive portion of a hydraulic jump 550 feet long occurs in the first 55 to 100 feet. The existing stilling basin has approximately 200 feet without further modification. If half of the jump for the maximum discharge can be contained within the stilling basin for the design flow of 250,000 ft^3/s, and if the full hydraulic jump from more frequent discharges can be contained within the basin, then it may be appropriate to maintain the existing basin without modifications. This should be carefully reviewed in the feasibility designs.

The basin will also need to be model studied during feasibility design for operational impacts with the power plant releases on both sides of the stilling basin.

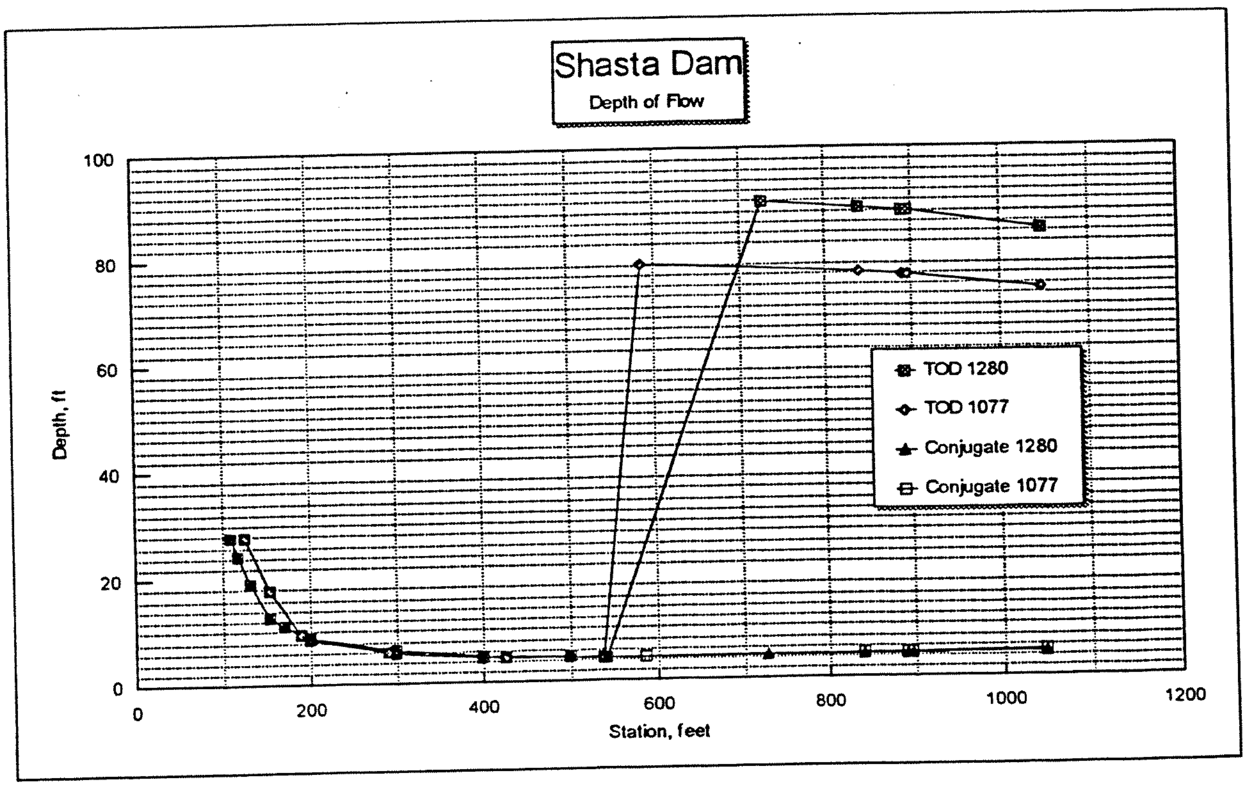


Figure 2 - Depth of Flow

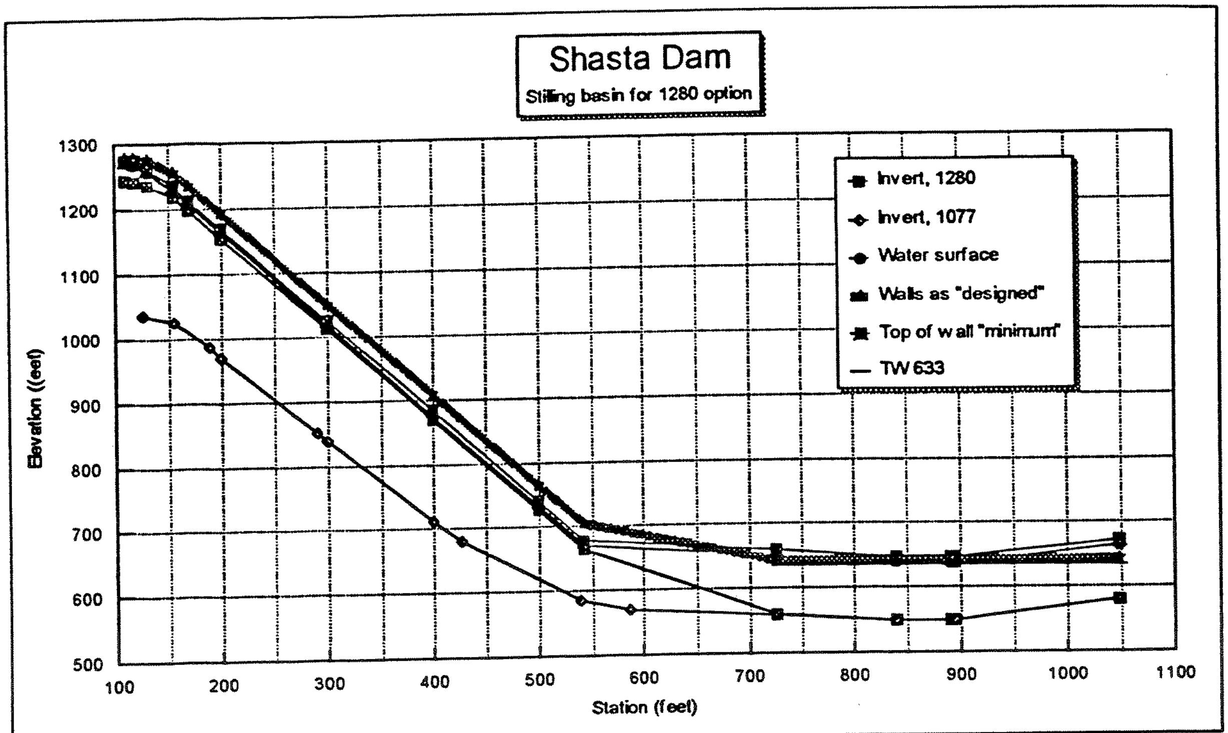


Figure 3 - Showing water surface & wall heights

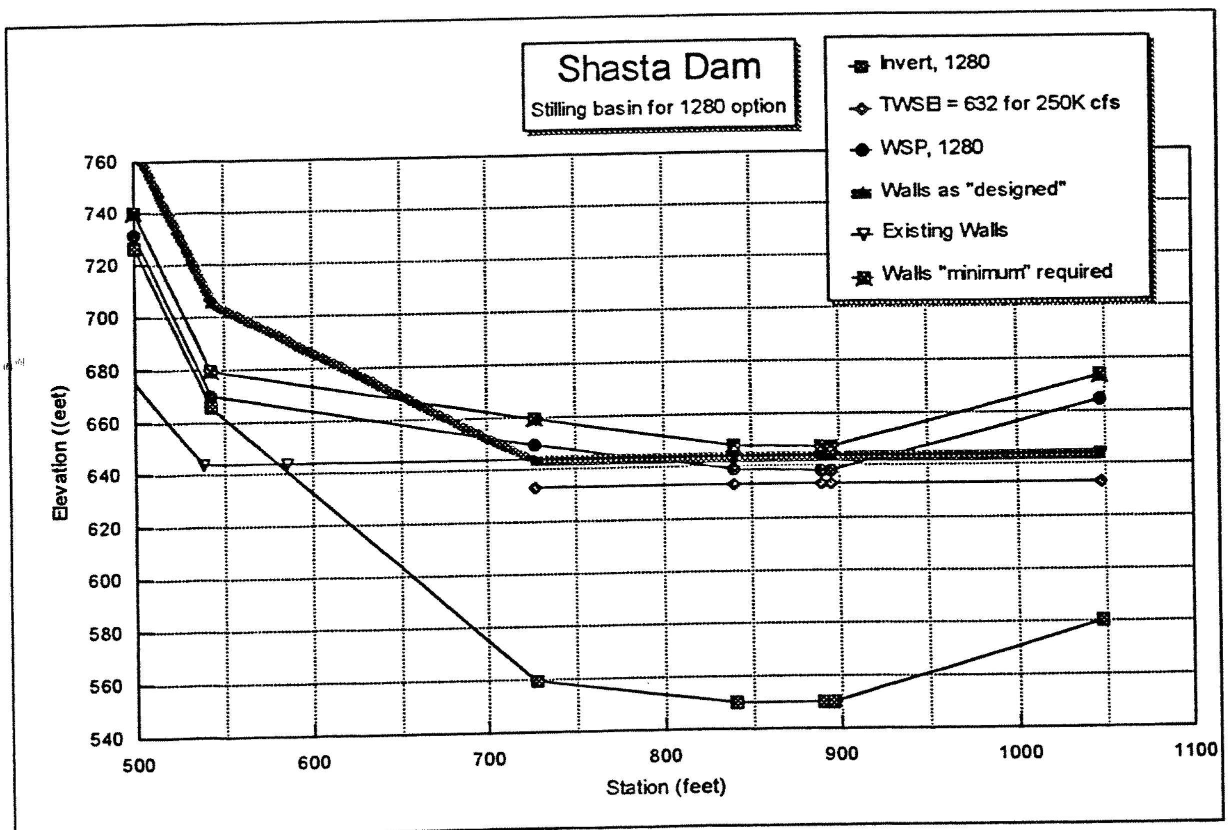


Figure 4 - Closer scale showing profile in stilling basin.

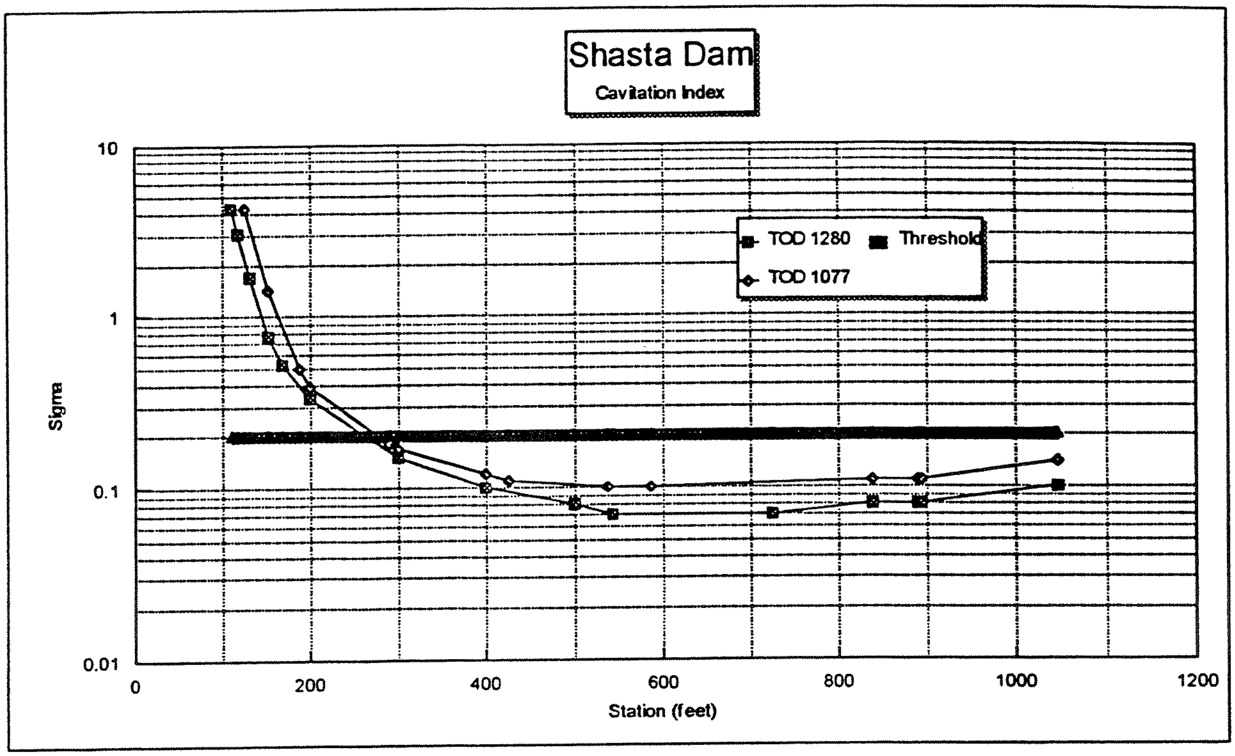


Figure 5 - Cavitation plot for Shasta Dam raised to El. 1280

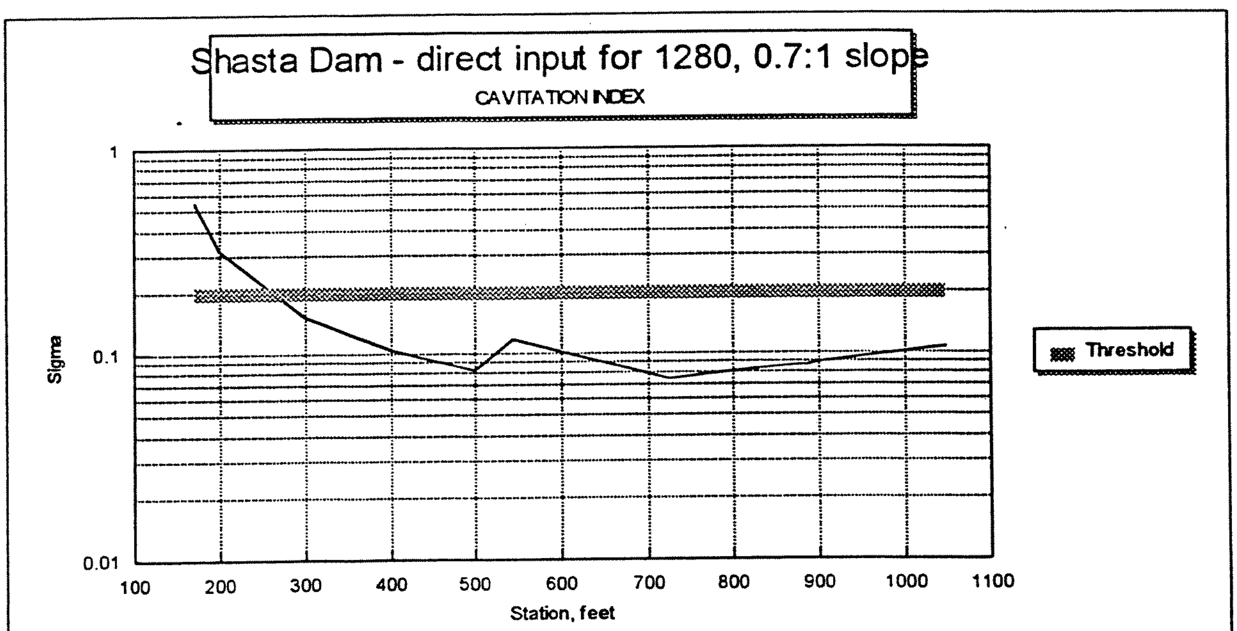


Figure 6 - Cavitation Index plot from Cavitation program

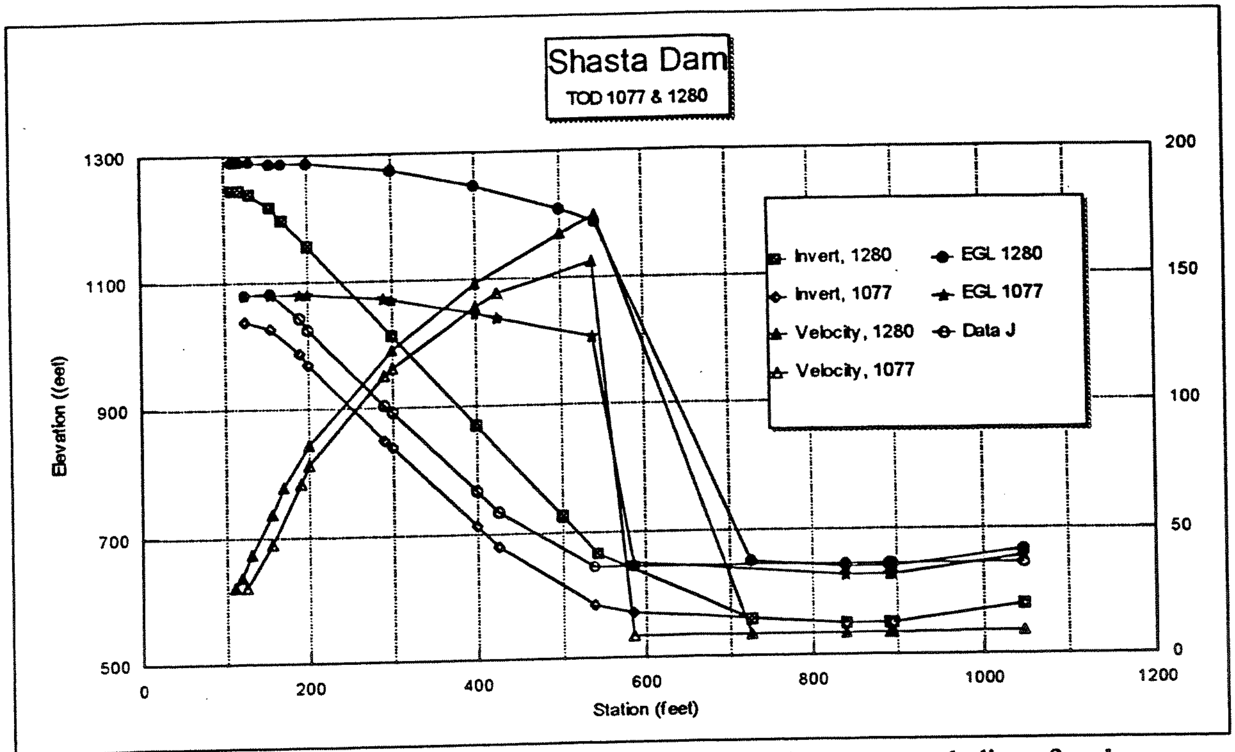


Figure 7 - Shasta Dam showing inverts, velocity profiles and energy grade lines for the existing condition and the raised structure.

APPENDIX C

EXTENDED RESERVOIR CAPACITY DATA FOR ENLARGED SHASTA RESERVOIR

Reservoir Elevation (feet)	Reservoir Capacity (acre-feet)
1067	4,552,000
1070	4,650,000
1080	5,000,000
1090	5,250,000
1100	5,600,000
1110	6,000,000
1120	6,350,000
1130	6,750,000
1140	7,100,000
1150	7,500,000
1160	7,950,000
1170	8,400,000
1180	8,850,000
1190	9,350,000
1200	9,850,000
1210	10,400,000
1220	10,900,000
1230	11,500,000
1240	12,000,000
1250	12,600,000
1260	13,200,000
1270	13,800,000
1280	14,400,000

Source: Based on data points provided by telephone communication from Bob Goss, MP regional office, on June 6, 1978; and corresponding plot.

CODE:D-8170 APPENDIX D-1 **ESTIMATE WORKSHEET** SHEET 1 OF 2

FEATURE:	PROJECT:
SHASTA DAM ENLARGEMENT - EL. 1280 (12-Feb-98)	CENTRAL VALLEY PROJECT
Dam Enlargement and Structures	DIVISION:
Appraisal Level Est. - Jan. 98	FILE: C:\123R4D\EST\SHASTA~1\TOTL1280.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Cofferdams for Left and Right Abutments			ls		$29,000,000
	2	Removal of Structures for Concrete Dam Raise			ls		$11,000,000
	3	Concrete Dam and RCC Wing Dam			ls		$1,100,000,000
	4	Spillway			ls		$24,000,000
	5	River Outlet Works					$80,000,000
	6	Dikes			ls		$98,000,000
		Dike # 1 - Centimudi Dike		$8,200,000	√		
		Dike # 2 - Bridge Bay Dike		$3,800,000	√		
		Dike # 3 - Jones Valley Dike		$55,000,000	√		
		Dike # 4 - Clickapudi Dike		$31,000,000	√		
	7	New Power Plant and Modifications to Existing Power Plant					$590,000,000
	8	230/ 525 - kv Switchyard					
		Electrical					$100,000,000
		Civil					$14,300,000
				SUBTOTAL SHEET 1	of 2		$2,046,300,000

QUANTITIES		PRICES	
BY T Hepler	CHECKED	BY: R. Baumgarten, L. Pedde, K.Copeland, C. Grush	CHECKED Craig A. Grush
DATE PREPARED	APPROVED	DATE 02/12/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1280

Relocation Cost Sheet

Appraisal Level Est. - Jan. 98

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\TOTL1280.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Resort Location and Land Rights			ls		$77,000,000
		Public Recreation Relocation			ls		$210,000,000
		Reservoir Clearing			ls		$46,000,000
		Enlarged Keswick Dam			ls		$68,000,000
		Enlarged Keswick Dam Powerplant			ls		$185,000,000
		Recreation Facilities			ls		$57,000,000
		Sacramento River Seepage Mitigation			ls		$86,000,000
		Bridge Bay Crossing (1)			ls		$340,000,000
		Southern Pacific Railroad Relocation (APR 84)					
		Earthwork			ls		$165,000,000
		Railroad			ls		$70,000,000
		Bridges			ls		$100,000,000
		Tunnels			ls		$120,000,000
		I-5 Relocation (APR 84)					
		Earthwork			ls		$105,000,000
		Railroad			ls		$41,000,000
		Bridges			ls		$81,000,000
		Interchanges			ls		$6,800,000
		Land Acquisition			ls		$1,250,000
	Note:	Relocation costs indexed from sheet provided by Tom Hepler. Most of the relocation costs have been indexed from Jan.82/Apr.84 to Oct. 1997 using BOR Construction Cost Indexes. We do not recommend indexing costs for more than a five year span. All relocation costs that have been indexed greater than 5 years should be recomputed using 1998 costs.		SUBTOTAL SHEET 2 of 2			$1,759,050,000
				SUBTOTAL SHEET 1 of 2			$2,046,300,000
						TOTAL	$3,805,350,000
		(1) - Provided by others than D8170					

QUANTITIES		PRICES	
BY T Hepler	CHECKED	BY: R. Baumgarten, L. Pedder, K.Copeland, C. Grush	CHECKED Craig A. Grush
DATE PREPARED	APPROVED	DATE 02/12/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1280

COFFERDAMS FOR LEFT AND RIGHT ABUTMENTS

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHASTA1A.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$1,000,000
	2	Diversion and care of releases during construction	D8130	Lump sum	ls		$4,500,000
	3	Removal and control of water during construction	D8130	Lump sum	ls		$750,000
	4	Excavation for cellular cofferdams, embankment (dr	D8130	275,000	yd3	$3.00	$825,000
	5	Excavation for cellular cofferdams, rock (dry)	D8130	25,000	yd3	$8.00	$200,000
	6	Furnish and install steel sheet piling, PSX-32	D8130	5,100	tons	$1,200.00	$6,120,000
	7	Furnish and place free-draining fill materials	D8130	185,000	yd3	$12.00	$2,220,000
	8	Concrete in anchor blocks	D8130	4,200	yd3	$85.00	$357,000
	9	Backfill concrete on foundation and abutments	D8130	16,000	yd3	$75.00	$1,200,000
	10	Furnishing and handling cement	D8130	3,300	tons	$100.00	$330,000
	11	Furnishing and handling pozzolan	D8130	830	tons	$60.00	$49,800
	12	Removal of steel sheet piling in cofferdams	D8130	5,100	tons	$600.00	$3,060,000
	13	Removal of free-draining fill materials	D8130	185,000	yd3	$4.00	$740,000
		Subtotal					**$21,351,800**
		Unlisted items @ 10 percent					**$1,648,200**
		Contract cost					**$23,000,000**
		Contingencies @ 25 percent					**$6,000,000**
		Field cost					**$29,000,000**

QUANTITIES		PRICES	
BY R. Benik	CHECKED T. Hepler	BY K. Copeland	CHECKED Craig A. Gush
DATE PREPARED 02/03/98	APPROVED	DATE 02/11/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1280

REMOVAL OF STRUCTURES FOR CONCRETE DAM RAISE

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHASTA1.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$380,000
	2	Removal of gantry crane and rails from dam crest	D8410	841,000	lbs	$0.30	$252,300
	3	Removal of spillway drum gates and frames	D8420	3,255,000	lbs	$0.60	$1,953,000
	4	Removal of drum gate control equipment	D8420	90,000	lbs	$0.75	$67,500
	5	Removal of structural steel in spillway bridge		976,000	lbs	$0.30	$292,800
	6	Removal of freight and passenger elevators	D8410	Lump sum	ls		$100,000
	7	Removal of concrete in spillway bridge and piers	D8130	2,800	yd3	$150.00	$420,000
	8	Removal of concrete in parapets and crest cantilever	D8130	5,730	yd3	$300.00	$1,719,000
	9	Removal of concrete in spillway crest	D8130	3,530	yd3	$200.00	$706,000
	10	Removal of concrete in spillway training walls	D8130	8,340	yd3	$150.00	$1,251,000
	11	Removal of concrete in spillway stilling basin	D8130	1,210	yd3	$80.00	$96,800
	12	Removal of concrete in hoist and elevator towers	D8130	1,500	yd3	$250.00	$375,000
	13	Removal of misc. concrete on both abutments	D8130	820	yd3	$70.00	$57,400
	14	Removal of left abutment concrete core wall during embankment excavation	D8130	6,100	yd3	$50.00	$305,000
		Subtotal					**$7,975,800**
		Unlisted items @ 10 percent					**$824,200**
		Contract cost					**$8,800,000**
		Contingencies @ 25 percent					**$2,200,000**
		Field cost					**$11,000,000**

QUANTITIES		PRICES	
BY R. Benik	**CHECKED** T. Hepler	**BY** R. Baumgarten	**CHECKED** Craig A. Gush
DATE PREPARED 02/03/98	**APPROVED**	**DATE** 02/11/98	**PRICE LEVEL** Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 2

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1280

CONCRETE DAM AND RCC WING DAMS

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHASTA1.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$70,000,000
	2	Excavation, open-cut, all classes (dry)	D8130	2,200,000	yd3	$6.00	$13,200,000
	3	Excavation for grouting and drainage tunnels	D8130	1,250	yd3	$250.00	$312,500
	4	Deleted					
	5	Furnish and install rock bolts (1-inch diameter)	D8130	6,000	lft	$25.00	$150,000
	6	Furnish and apply 6" shotcrete tunnel support	D8130	1,600	yd2	$50.00	$80,000
	7	Cleanup for foundation inspection	D8130	74,000	yd2	$8.00	$592,000
	8	Drilling foundation grout holes (A- and B-holes)	D8130	142,000	lft	$26.00	$3,692,000
	9	Furnishing, mixing, and pressure grouting foundatio	D8130	110,000	bags	$18.00	$1,980,000
	10	Drilling foundation drain holes from galleries	D8130	66,000	lft	$30.00	$1,980,000
	11	Constructing 5" and 18" formed drains in dam	D8130	80,000	lft	$26.00	$2,080,000
	12	Furnishing and installing flat drains at dam contact	D8130	44,000	lft	$10.00	$440,000
	13	Shaping and dental concrete	D8130	80,000	yd3	$90.00	$7,200,000
	14	Mass concrete in dam (10-foot lifts)	D8130	5,900,000	yd3	$75.00	$442,500,000
	15	Roller-compacted concrete in wing dams	D8130	1,500,000	yd3	$24.00	$36,000,000
	16	Concrete in slip-formed facing elements	D8130	65,000	yd3	$150.00	$9,750,000
	17	Concrete in crest cantilever	D8130	15,400	yd3	$200.00	$3,080,000
	18	Concrete in sidewalks and parapet walls	D8130	1,820	yd3	$350.00	$637,000
	19	Concrete in elevator and hoist towers	D8130	1,500	yd3	$600.00	$900,000

QUANTITIES		PRICES	
BY R. Benik	CHECKED T. Hepler	BY R. Baumgarten	CHECKED Craig A. Gush
DATE PREPARED 02/06/98	APPROVED	DATE 02/11/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1280

CONCRETE DAM AND RCC WING DAMS (CONT.)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHASTA1.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	20	Concrete in grouting and drainage tunnel floors	D8130	200	yd3	$250.00	$50,000
	21	Furnishing and handling cement	D8130	887,000	tons	$90.00	$79,830,000
	22	Furnishing and handling pozzolan	D8130	470,000	tons	$50.00	$23,500,000
	23	Temperature control of mass concrete	D8130	5,900,000	yd3	$6.00	$35,400,000
	24	Furnishing and placing metal pipe for temp. control	D8130	2,000,000	lft	$5.00	$10,000,000
	25	Furnishing and placing metal pipe for grouting contraction joints in dam	D8130	1,000,000	lbs	$2.50	$2,500,000
	26	Furnishing, mixing, and pressure grouting contractio joints and temperature control systems in dam	D8130	60,000	bags	$12.00	$720,000
	27	Furnishing and installing 12-inch PVC waterstop	D8130	350,000	lft	$10.00	$3,500,000
	28	Furnishing and placing reinforcing bars	D8130	2,500,000	lbs	$0.50	$1,250,000
	29	Furnishing and installing instrumentation	D8130	Lump sum	ls		$10,500,000
	30	Furnishing and installing two elevators	D8410	Lump sum	ls		$900,000
	31	Gantry crane and rails, 125 ton, right side	D8410	605,000	lbs	$3.00	$1,815,000
	32	Gantry crane and rails, 175 ton, left side	D8410	705,000	lbs	$3.00	$2,115,000
	33	Ventilating systems for galleries (10 kw system)		12,600	sf	$5.00	$63,000
	34	Lighting systems for dam and galleries (82 kw sys)		160,500	sf	$6.50	$1,043,250
		Subtotal					**$767,759,750**
		Unlisted items @ 15 percent					**$112,240,250**
		Contract cost					**$880,000,000**
		Contingencies @ 25 percent					**$220,000,000**
		Field cost					**$1,100,000,000**

QUANTITIES		PRICES	
BY R. Benik	CHECKED T. Hepler	BY R. Baumgarten	CHECKED Craig A. Funk
DATE PREPARED 02/06/98	APPROVED	DATE 02/11/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1280

SPILLWAY

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHASTA1.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$810,000
	2	Concrete in extended stilling basin floor	D8130	4,400	yd3	$240.00	$1,056,000
	3	Concrete in extended stilling basin walls	D8130	6,200	yd3	$280.00	$1,736,000
	4	Concrete in spillway training walls on d/s face	D8130	5,000	yd3	$350.00	$1,750,000
	5	Concrete in spillway bridge piers	D8130	5,700	yd3	$250.00	$1,425,000
	6	Concrete in spillway bridge and operating deck	D8130	1,400	yd3	$600.00	$840,000
	7	Furnishing and handling cement	D8130	5,200	tons	$100.00	$520,000
	8	Furnishing and handling pozzolan	D8130	1,300	tons	$60.00	$78,000
	9	Furnishing and placing reinforcing bars	D8130	3,000,000	lbs	$0.50	$1,500,000
	10	Six spillway radial gates, 55 by 27.5 feet	D8420	1,155,000	lbs	$3.00	$3,465,000
	11	Six sets, embedded metalwork for radial gates	D8420	284,000	lbs	$3.50	$994,000
	12	Six radial gate hoists, 164,000 lb capacity each	D8410	295,200	lbs	$7.00	$2,066,400
	13	Gantry crane and rails, 60 ton capacity	D8410	246,000	lbs	$3.50	$861,000
		Subtotal					**$17,101,400**
		Unlisted items @ 10 percent					**$1,898,600**
		Contract cost					**$19,000,000**
		Contingencies @ 25 percent					**$5,000,000**
		Field cost					**$24,000,000**

QUANTITIES		PRICES	
BY T. Hepler	CHECKED	BY R. Baumgarten	CHECKED Craig a. Lusk
DATE PREPARED 02/03/98	APPROVED	DATE 02/11/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1280

RIVER OUTLETS

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHASTA1A.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$2,800,000
	2	Removal of eighteen coaster gate frames, u/s face		1,090,000	lbs	$0.80	$872,000
	3	Removal of fourteen 96-inch outlet gates	D8420	1,820,000	lbs	$0.35	$637,000
	4	Removal of four 102-inch tube valves	D8420	1,032,000	lbs	$0.35	$361,200
	5	Removal of steel liners for outlets (740 lin ft)	D8420	500,000	lbs	$0.50	$250,000
	6	Removal of gate and valve operating systems	D8420	36,000	lbs	$0.75	$27,000
	7	Excavation of concrete for 18 new gate chambers	D8130	3,000	yd3	$350.00	$1,050,000
	8	Concrete in 18 new gate chambers	D8130	2,700	yd3	$350.00	$945,000
	9	Furnishing and handling cement	D8130	620	tons	$110.00	$68,200
	10	Furnishing and handling pozzolan	D8130	150	tons	$70.00	$10,500
	11	Furnishing and placing reinforcing bars	D8130	400,000	lbs	$0.60	$240,000
	12	One 11- by 11-foot bulkhead gate, 540-ft head	D8420	132,000	lbs	$4.00	$528,000
	13	Bulkhead gate guides for 18 outlets, u/s face	D8420	1,950,000	lbs	$3.00	$5,850,000
	14	Bulkhead gate lifting frame	D8420	5,000	lbs	$3.00	$15,000
	15	Eight 102-inch ring-follower gates, 540-ft head	D8420	1,360,000	lbs	$6.00	$8,160,000
	16	Sixteen 102-inch ring-follower gates, 440-ft head	D8420	2,656,000	lbs	$6.00	$15,936,000
	17	Twelve 102-inch ring-follower gates, 340-ft head	D8420	1,944,000	lbs	$6.00	$11,664,000
	18	Control systems for 36 gates	D8420	108,000	lbs	$15.00	$1,620,000

QUANTITIES		PRICES	
BY J. Ellingson	CHECKED T. Hepler	BY K. Copeland	CHECKED Craig A. Gush
DATE PREPARED	APPROVED	DATE 02/11/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1280

RIVER OUTLETS (CONT.)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHASTA1A.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	19	Furnish and install 102-inch steel liners for outlets	D8420	2,600,000	lbs	$2.50	$6,500,000
	20	Backfill grouting for 102-inch steel liners (540 lin ft)	D8130	8,000	bags	$20.00	$160,000
	21	Extend 36-inch steel piping for air vents (El. 988)	D8420	35,000	lbs	$8.00	$280,000
	22	Furnish and install air valves and filling lines	D8420	2,000	lbs	$15.00	$30,000
		Subtotal					**$58,003,900**
		Unlisted items @ 10 percent					**$5,996,100**
		Contract cost					**$64,000,000**
		Contingencies @ 25 percent					**$16,000,000**
		Field cost					**$80,000,000**

QUANTITIES		PRICES	
BY J. Ellingson	CHECKED T. Hepler	BY	CHECKED Craig A. Gush
DATE PREPARED	APPROVED	DATE 02/11/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE:
SHASTA DAM ENLARGEMENT
CENTIMUDI DIKE - R. EL 1280
DIKE No. 1

11-Feb-98

PROJECT:
CENTRAL VALLEY , CALIFORNIA

DIVISION:

FILE:
C:\123R4D\EST\SHASTA~1\TORRESDK.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization			L.S		$290,000
	2	Clearing and grubbing 6" to waste		32,900	S Y	$1.75	$57,575
	3	**Foundation treatment**					
	3.a	Surface excavation		38,100	CY	$5.00	$190,500
	3.b	Core trench excavation		25,900	CY	$7.00	$181,300
	3.c	Pipe for grouting w/fittings,3.5' x2"Dia.		126	EA	$60.00	$7,560
	3.d	Drill Setup for Grout holes		126	EA	$110.00	$13,860
	3.e	Drilling grout holes, 40' deep, each		5,040	L F	$40.00	$201,600
	3.f	Casing grout holes (Assume 10%)		504	L F	$14.00	$7,056
	3.g	Hookups for grout holes		126	EA	$70.00	$8,820
	3.h	Pressure grouting		5,040	BAGS	$9.00	$45,360
	3.i.	Cement for pressure grouting		5,040	BAGS	$7.50	$37,800
	3.j	Water tests		252	EA	$70.00	$17,640
	3.k	Slush grout		38,100	S Y	$14.00	$533,400
	3.l	Dental concrete		100	CY	$250.00	$25,000
	4	Exc.(5 mi. haul), placement and compaction zone 1		135,530	C Y	$8.50	$1,152,005
	5	Exc.(5 mi. haul), placement and compaction zone 2		165,340	C Y	$8.00	$1,322,720
	6	Chimney drain and drainage blanket (assume borrow)		28,120	C Y	$28.00	$787,360
	7	Riprap (assume borrow)		13,130	C Y	$35.00	$459,550
	8	Riprap bedding (assume borrow)		6,570	C Y	$30.00	$197,100
	6	**Toe drain**					
		Excavation		9,340	C Y	$7.00	$65,380
		Drain material		9,320	C Y	$32.00	$298,240
		Perforated PVC 12" pipe		630	L F	$37.00	$23,310
		Weir Box		1	EA	$5,000.00	$5,000
	7	Instrumentation		1	LS		$65,000
		Subtotal					**$5,993,136**
		Unlisted items (10%)					**$606,864**
		Contract cost					**$6,600,000** √
		Contingencies (25%)					**$1,600,000**
		Field Cost					**$8,200,000**

QUANTITIES		PRICES	
BY R. L. Torres	CHECKED R. L. Webb	BY R. Baumgarten	CHECKED Craig A. Gush
DATE PREPARED Feb. 4, 1998	APPROVED	DATE 02/11/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE:
SHASTA DAM ENLARGEMENT
BRIDGE BAY DIKE - R. EL. 1280
DIKE No. 2

11-Feb-98

PROJECT:
CENTRAL VALLEY , CALIFORNIA

DIVISION:

FILE:
C:\123R4D\EST\SHASTA~1\TORRESDK.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization			L.S		$130,000
	2	Clearing and grubbing 6" to waste		16,000	S Y	$2.00	$32,000
	3	Foundation treatment					
	3.a	Surface excavation		10,920	CY	$7.00	$76,440
	3.b	Core trench excavation		14,900	CY	$10.00	$149,000
	3.c	Pipe for grouting w/fittings,3.5' x2"Dia.		88	EA	$65.00	$5,720
	3.d	Drill Setup for Grout holes		88	EA	$120.00	$10,560
	3.e	Drilling grout holes, 40' deep, each		3,520	L F	$45.00	$158,400
	3.f	Casing grout holes (Assume 10%)		352	L F	$15.00	$5,280
	3.g	Hookups for grout holes		88	EA	$80.00	$7,040
	3.h	Pressure grouting		3,520	BAGS	$10.00	$35,200
	3.i	Cement for pressure grouting		3,520	BAGS	$8.00	$28,160
	3.j	Water tests		176	EA	$80.00	$14,080
	3.k	Slush grout		10,920	S Y	$15.00	$163,800
	3.l	Dental concrete		100	CY	$250.00	$25,000
	4	Exc.(5 mi. haul), placement and compaction zone 1		51,320	C Y	$9.00	$461,880
	5	Exc.(5 mi. haul), placement and compaction zone 2		66,900	C Y	$8.50	$568,650
	6	Chimney drain and drainage blanket (assume borrow)		13,000	C Y	$30.00	$390,000
	7	Riprap (assume borrow)		6,080	C Y	$40.00	$243,200
	8	Riprap bedding (assume borrow)		3,040	C Y	$35.00	$106,400
	6	**Toe drain**					
		Excavation		2,040	C Y	$7.00	$14,280
		Drain material		2,030	C Y	$35.00	$71,050
		Perforated PVC 12" pipe		440	L F	$40.00	$17,600
		Weir Box		1	EA	$5,000.00	$5,000
	7	Instrumentation		1	LS		$30,000
		Subtotal					**$2,748,740** √
		Unlisted items (10%)					**$251,260** √
		Contract cost					**$3,000,000** √
		Contingencies (25%)					**$800,000** √
		Field Cost					**$3,800,000** √

QUANTITIES		PRICES	
BY R.L. Torres	CHECKED R. L. Webb	BY R. Baumgarten	CHECKED Craig A. Gush
DATE PREPARED Feb. 4, 1998	APPROVED	DATE 02/11/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT
JONES VALLEY DIKE - R. EL 1280
DIKE No. 3

PROJECT:
CENTRAL VALLEY , CALIFORNIA

DIVISION:

FILE:
C:\123R4D\EST\SHASTA~1\TORRESDK.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization			L.S		$1,900,000
	2	Clearing and grubbing 6" to waste		200,000	S Y	$1.50	$300,000
	3	**Foundation treatment**					
		Surface excavation		135,400	CY	$4.00	$541,600
		Core trench excavation		86,000	CY	$5.00	$430,000
		Pipe for grouting w/fittings,3.5' x2"Dia.		340	EA	$50.00	$17,000
		Drill Setup for Grout holes		340	EA	$100.00	$34,000
		Drilling grout holes, 40'		13,600	L F	$30.00	$408,000
		Casing grout holes (Assume 10%)		1,360	L F	$12.00	$16,320
		Hookups for grout holes		340	EA	$50.00	$17,000
		Pressure grouting		13,600	BAGS	$8.00	$108,800
		Cement for pressure grouting		13,600	BAGS	$7.00	$95,200
		Water tests		680	EA	$65.00	$44,200
		Slush grout		135,400	S Y	$10.00	$1,354,000
		Dental concrete		200	CY	$200.00	$40,000
	4	Exc. (5 mi haul), placement and compaction zone 1		1,516,000	C Y	$7.00	$10,612,000
	5	Exc. (5 mi haul), placement and compaction zone 2		2,533,000	C Y	$6.50	$16,464,500
	6	Chimney drain and drainage blanket (assume borrow)		187,200	C Y	$18.00	$3,369,600
	7	Riprap (assume borrow)		83,800	C Y	$24.00	$2,011,200
	8	Riprap bedding (assume borrow)		41,900	C Y	$18.00	$754,200
	9	**Toe drain**					
		Excavation		25,190	C Y	$6.00	$151,140
		Drain material		25,140	C Y	$25.00	$628,500
		Perforated PVC 12" pipe		1,700	L F	$30.00	$51,000
		Weir Box		1	EA	$5,000.00	$5,000
	7	Instrumentation		1	LS		$450,000
		Subtotal					**$39,803,260**
		Unlisted items (10%)					**$4,196,740** ✓
		Contract cost					**$44,000,000** ✓
		Contingencies (25%)					**$11,000,000**
		Field Cost					**$55,000,000** ✓

QUANTITIES		PRICES	
BY R. L. Torres	CHECKED R. L. Webb	BY R.Baumgarten	CHECKED Craig a. Lusk
DATE PREPARED Feb. 4, 1998	APPROVED	DATE 02/11/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE:
SHASTA DAM ENLARGEMENT
CLICKAPUDI DIKE - R. EL 1280
DIKE No. 4

11-Feb-98

PROJECT:
CENTRAL VALLEY , CALIFORNIA

DIVISION:

FILE:
C:\123R4D\EST\SHASTA~1\TORRESDK.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization			L.S		$1,100,000
	2	Clearing and grubbing 6" to waste		200,000	S Y	$1.50	$300,000
	3	**Foundation treatment**					
	3.a	Surface excavation		84,900	CY	$4.00	$339,600
	3.b	Core trench excavation		53,900	CY	$6.00	$323,400
	3.c	Pipe for grouting w/fittings,3.5' x2"Dia.		320	EA	$50.00	$16,000
	3.d	Drill Setup for Grout holes		320	EA	$100.00	$32,000
	3.e	Drilling grout holes, 40' deep, each		12,800	L F	$30.00	$384,000
	3.f	Casing grout holes (Assume 10%)		1,280	L F	$12.00	$15,360
	3.g	Hookups for grout holes		320	EA	$50.00	$16,000
	3.h	Pressure grouting		12,800	BAGS	$8.00	$102,400
	3.i	Cement for pressure grouting		12,800	BAGS	$7.00	$89,600
	3.j	Water tests		640	EA	$65.00	$41,600
	3.k	Slush grout		80,200	S Y	$11.00	$882,200
	3.l	Dental concrete		200	CY	$200.00	$40,000
	4	Exc.(5 mi. haul), placement and compaction zone 1		733,000	C Y	$7.75	$5,680,750
	5	Exc.(5 mi. haul), placement and compaction zone 2		1,179,000	C Y	$7.25	$8,547,750
	6	Chimney drain and drainage blanket (assume borrow)		97,000	C Y	$22.00	$2,134,000
	7	Riprap (assume borrow)		45,000	C Y	$28.00	$1,260,000
	8	Riprap bedding (assume borrow)		22,500	C Y	$22.00	$495,000
	6	**Toe drain**					
		Excavation		23,000	C Y	$6.00	$138,000
		Drain material		23,000	C Y	$25.00	$575,000
		Perforated PVC 12" pipe		1,500	L F	$30.00	$45,000
		Weir Box		1	EA	$5,000.00	$5,000
	7	Instrumentation		1	LS		$250,000
		Subtotal					**$22,812,660** ✓
		Unlisted items (10%)					**$2,187,340** ✓
		Contract cost					**$25,000,000** ✓
		Contingencies (25%)					**$6,000,000** ✓
		Field Cost					**$31,000,000** ✓

QUANTITIES		PRICES	
BY R. L. Torres	CHECKED R. L. Webb	BY R. Baumgarten	CHECKED Craig a. Gush
DATE PREPARED Feb. 4, 1998	APPROVED	DATE 02/11/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET_____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

POWER OUTLETS:
MODIFICATIONS TO EXISTING
TEMPERATURE CONTROL DEVICE

PROJECT: 10:26 AM
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\WKSHTS\SHSTA\SUM1280.WK4 A

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Remove existing 17 TCD gate hoists	D8410	884,000	LBS	$0.25	$221,000
		Remove existing electrical control equipment	D8430	1	LS	$5,200.00	$5,200
		(5 MCCs, 1 Distribution switchboard)					
		Remove existing miscellaneous metalwork	D8120	175,000	LBS	$0.30	$52,500
		Remove existing structural steel at El. 1067.5	D8120	750,000	LBS	$0.25	$187,500
		F&I new trashrack panels in the dry at El. 1067.5	D8410	477,000	LBS	$2.50	$1,192,500
		F&I new structural steel trashrack support structure in dry at El. 1067.5	D8120	630,700	LBS	$2.50	$1,576,750
		F&I new structural steel hoist support structure in dry at El. 1275.0	D8120	1,180,000	LBS	$2.00	$2,360,000
		F&I 17 new TCD gate hoists (150,000 lbs. cap.)	D8410	900,000	LBS	$7.00	$6,300,000
		F&I new miscellaneous metalwork at El. 1275.0	D8120	200,000	LBS	$5.00	$1,000,000
	*	F&I new electrical control equipment	D8430	1	LS	$400,000.00	$400,000
		(5 MCCs, 1 Distribution switchboard, conduit)					
		(Assume quantities are same as original TCD est.)					
		SHEET A SUBTOTAL					$13,295,450 v

QUANTITIES		PRICES	
BY LaFond, Christensen, Ritt	CHECKED	BY L. PEDDE	CHECKED Craig A. Gust
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL APPR.

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF ______

FEATURE: 12-Feb-98 **SHASTA DAM ENLARGEMENT** ***EL. 1280*** **POWER OUTLETS:** **MODIFICATIONS TO EXISTING** **PENSTOCK INTAKES**	**PROJECT:** CENTRAL VALLEY PROJECT **DIVISION:** SHASTA **FILE:** C:\WKSHTS\SHSTA\SUM1280.WK4 B

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Remove existing gate hoist structure to El. 1068.75	D8110	125	CY	$200.00	$25,000
		Remove existing misc. metalwork	D8110	8,800	LBS	$0.30	$2,640
		Remove 5 existing coaster gates and operators	D8420	1	LS	$250,000.00	$250,000
		assuming approx. 1M lbs					
		Remove 5 exist. coaster gate frames btwn El. 803 and	D8420	562,000	LBS	$0.25	$140,500
		827 (Assume stoplogs allow work in dry)					
		Plug control rooms and stairs to 1065 gallery w/conc.	D8110	100	CY	$250.00	$25,000
		Extend existing gate hoist structure from El 1068.75					
		to El. 1280.0:					
		a. Reinforced Concrete	D8120	3,225	CY	$350.00	$1,128,750
		b. Reinforcement (120LBS/CY)	D8120	387,000	LBS	$0.60	$232,200
		c. Cement (6sacks/CY)	D8120	910	TONS	$110.00	$100,100
		F&I miscellaneous metalwork (hatches, grating)	D8120	10,000	LBS	$4.00	$40,000
		F&I 5 new wheel-mounted gates, H=473', (16'x25')	D8420	1,080,000	LBS	$2.50	$2,700,000
		F&I 5 hoists for wheel-mounted gates	D8420	633,000	LBS	$7.00	$4,431,000
		F&I 5 control systems for wheel-mounted gates	D8430	15,000	LBS	$15.00	$225,000
		F&I new gate guides and frames	D8420	843,000	LBS	$3.50	$2,950,500
		Furnish 1 set of new stoplogs (El. 797.59 - El. 1275)	D8410	2,400,000	LBS	$2.00	$4,800,000
		Furnish 1 stoplog lifting frame	D8410	5,000	LBS	$2.00	$10,000
		F&I cast steel stoplog guides - El. 1077.5 to El. 1280	D8410	396,000	LBS	$2.50	$990,000
		F&I electrical system for gate operation	D8430	1	LS	$75,000.00	$75,000
		SHEET B SUBTOTAL					$18,125,690 √

QUANTITIES		PRICES	
BY LaFond, Arrington, Christensen	CHECKED	BY	CHECKED Craig A. Gurh
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

**POWER OUTLETS:
MODIFICATIONS TO EXISTING
PENSTOCKS (sht 1 of 2)**

PROJECT: CENTRAL VALLEY PROJECT

DIVISION: SHASTA

FILE: C:\WKSHTS\SHSTA\SUM1280.WK4 C

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Excavate five 17-foot diameter tunnels through dam	D8110	1	LS	$1,352,000.00	$1,352,000
		along existing 15-foot diameter penstocks to					
		remove existing penstocks (5x250) = 1,250 FT					
		(Intake El. 815, Use new stoplogs					
		on upstream face as temporary bulkhead)					
		(Rebar and steel supports will be encountered)					
		(Weight of penstock to be removed= 2,220,000 LBS)		2,220,000	LB	$0.35	
		(Volume of concrete to be removed= 2,300 CY)		2,300	CY	$250.00	
		Remove existing concrete penstock anchors	D8120	8,900	CY	$100.00	$890,000
		(10 anchor blocks)					
		Furnish five new 15-foot diameter steel penstocks	D8420	3,100,000	LBS	$0.90	$2,790,000
		Install new 15-foot diameter penstocks	D8110	1,250	LF	$3,720.00	$4,650,000
		in excavated 17-foot diameter tunnel					
		Install@ $1.50/lb & 12480lb/ft					
		Place concrete in void between 17-foot diameter	D8110	2,300	CY	$250.00	$575,000
		tunnel and 15-foot diameter penstock					
		Furnish cement for penstock concreting (6 sacks/CY)	D8110	650	TONS	$110.00	$71,500
		FRP 25 add'l penstock foundations: (EQ Supports)					
		Reinforced Concrete	D8120	2,000	CY	$350.00	$700,000
		Reinforcement (100LBS/CY)	D8120	200,000	LBS	$0.60	$120,000
		Cement (6sacks/CY)	D8120	565	TONS	$110.00	$62,150
		Excavate for new valve vault (adjacent to exist PP)	D8120	18,500	CY	$20.00	$370,000
		(Assume rock excavation.)					
		Concrete for new valve vault	D8120	8,900	CY	$350.00	$3,115,000
		SHEET C SUBTOTAL					$14,695,650

QUANTITIES		PRICES	
BY Anderson, Frisz	CHECKED	BY	CHECKED Craig A. Grush
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF ______

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

POWER OUTLETS:
MODIFICATIONS TO EXISTING
PENSTOCKS (sht 2 of 2)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION: SHASTA

FILE: C:\WKSHTS\SHSTA\SUM1280.WK4 D

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Furnish and place rebar in new valve vault (100#/CY)	D8120	890,000	LBS	$0.55	$489,500
		Furnish cement for new valve vault (6sacks/CY)	D8120	2,500	TONS	$110.00	$275,000
		Miscellaneous Metalwork for new valve vault (ladders, hatches, walkways)	D8120	190,000	LBS	$4.00	$760,000
		F&I five - 180-inch dia. - Class 300 psi butterfly valves (w/air valves and 16" dia. filling valves)	D8420	750,000	LBS	$6.00	$4,500,000
		F&I five control systems for 180-inch valves APPROX 3000 LB/EA	D8420	5	EA	$20,000.00	$100,000
		F&I steel piping for 16" dia. filling lines	D8420	2,500	LBS	$10.00	$25,000
		F&I Electrical systems for 180-inch valves ref: CAP [84]	D8430	1	LS	$70,000.00	$70,000
		SHEET D SUBTOTAL					$6,219,500 √

QUANTITIES		PRICES	
BY Anderson, Frisz	CHECKED	BY	CHECKED Craig A. Funk
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF ____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

POWER OUTLETS:
NEW PENSTOCK INTAKES
ON LEFT ABUTMENT (sht 1 of 2)

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\WKSHTS\SHSTA\SUM1280.WK4 E

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Excavate 10'x1'x 1.5" d. horiz . keys at 5' ctrs.					
		vertically into existing concrete face:					
		in dry btwn El. 1010 and 1080	D8110	140	EA	$10.00	$1,400
		in wet btwn El. 950 and 1010	D8110	120	EA	$50.00	$6,000
		Excavate 2 -foot deep by 3-foot wide slots into	D8110	900	LF	$200.00	$180,000
		existing concrete for gate frames/guides					
		between El. 955 and 1015					
		Excavate 2 -foot deep by 5-foot wide key into	D8110	250	LF	$75.00	$18,750
		existing concrete for base slab at El. 950					
		Drill holes for anchor bars and grout bars in place:					
		in dry btwn El. 1010 and 1080	D8110	4,600	LF	$25.00	$115,000
		in wet btwn El. 960 and 1010	D8110	5,300	LF	$25.00	$132,500
		db					
		Concrete for new intake structures above El. 1010.0	D8110	22,500	CY	$350.00	$7,875,000
		Concrete for new intake structures below El. 1010.0	D8110	3,200	CY	$350.00	$1,120,000
		Blockout concrete for new guides and frames	D8110	195	CY	$300.00	$58,500
		between El. 955 and 1015					
		Furnish and place rebar for new intakes (110lbs/CY)	D8110	2,827,000	LBS	$0.55	$1,554,850
		Furnish cement for new intakes (6 sacks/CY)	D8110	7,300	TONS	$110.00	$803,000
		Furnish and install structural steel for new intake	D8120	2,000,000	LBS	$2.00	$4,000,000
		structures between El. 1010 and 880					
		Furnish and install steel bridge plank - 9x3 -	D8120	24,200	SF	$23.00	$556,600
		3 gage - 15.3 lb/sf - btwn El. 1010 and 880					
		$1.50/LB					
		SHEET E SUBTOTAL					$16,421,600 √

QUANTITIES		PRICES	
BY LaFond	CHECKED	BY	CHECKED Craig A. Fusch
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

POWER OUTLETS:
NEW PENSTOCK INTAKES
ON LEFT ABUTMENT (sht 2 of 2)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION: SHASTA

FILE: C:\WKSHTS\SHSTA\SUM1280.WK4 F

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Install dam connections for steel intake structure	D8120	60	EA	$25,000.00	$1,500,000
		(2 DCs/ intake at Els. 1005, 985, 965, 945, 915, 880)					
		(Assume six 2"dia. anchors and 5,000# steel/ DC)					
		F&I miscellaneous metalwork at El. 1280	D8120	60,000	LBS	$5.00	$300,000
		F&I 5 Wheel-mounted gates (H=320', 20'x31')	D8420	- 1,647,000	LBS	$2.50	$4,117,500
		ref: Minidoka & Waddell					
		F&I 5 sets of frames and guides for whl.-mtd gates	D8420	1,307,000	LBS	$3.50	$4,574,500
		F&I 5 hoists for wheel-mounted gates	D8420	982,000	LBS	$7.00	$6,874,000
		F&I 5 control systems for wheel-mounted gates	D8420	15,000	LBS	$15.00	$225,000
		F&I 5 sets cast steel stoplog guides and seats	D8410	680,000	LBS	$2.50	$1,700,000
		Furnish 1 set of new stoplogs (El. 955 - El. 1275)	D8410	1,820,000	LBS	$2.00	$3,640,000
		Furnish 1 stoplog lifting frame	D8410	5,000	LBS	$2.00	$10,000
		F&I steel trashracks at following elevations:					
		El. 1275 - 1125 (5 tot.)	D8410	1,013,000	LBS	$2.50	$2,532,500
		El. 990 - 890 (5 tot.)	D8410	675,000	LBS	$2.50	$1,687,500
		F&I hoist-operated multi-level steel gates:					
		Upper Gate (45' x 100') (5 tot.)	D8410	1,225,000	LBS	$4.00	$4,900,000
		Lower Gate (45' x 100') (5 tot.)	D8410	1,225,000	LBS	$4.00	$4,900,000
		F&I steel guides for muti-level gates and trashracks	D8410	237,000	LBS	$2.20	$521,400
		F&I 10 multi-level gate hoists - 350,000 lbs. cap.	D8410	1,000,000	LBS	$7.00	$7,000,000
		F&I temperature monitoring equipment	D8410	1	LS	$100,000.00	$100,000
	?	F&I electrical equipment for multi-level intake	D8430	1	LS	$150,000.00	$150,000
		SHEET F SUBTOTAL					$44,732,400

QUANTITIES		PRICES	
BY LaFond, Arrington, Christensen, Ritt	CHECKED	BY	CHECKED Craig A. Kirsch
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

POWER OUTLETS:
NEW PENSTOCKS ON LEFT ABUTMENT

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\WKSHTS\SHSTA\SUM1280.WK4 G

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Excavate five 22-foot diameter tunnels through dam	D8110	20,000	CY	$150.00	$3,000,000
		for new 20-foot diameter penstocks (inclined)					
		(Intake El. 970, Reservoir El. 1010)					
		Excavation for penstocks, anchors, and foundations	D8120	16,000	CY	$15.00	$240,000
		Furnish five new 20-foot dia. steel penstocks	D8420	22,500,000	LBS	$0.90	$20,250,000
		total length = 1425+3700=5125'					
		Install new 20-foot diameter penstocks	D8110	1,425	LF	$6,600.00	$9,405,000
		in excavated 22-foot diameter tunnel (285' ea.)					
		install @$1.50/lb @ 4390#/ft					
		Place concrete in void between 22-foot diameter	D8110	3,500	CY	$250.00	$875,000
		tunnel and 20-foot diameter penstock					
		Furnish cement for penstock concreting (6 sacks/CY)	D8110	990	TONS	$110.00	$108,900
		FRP new penstock foundations and anchors:					
		Reinforced Concrete	D8120	15,000	CY	$350.00	$5,250,000
		Reinforcement (100LBS/CY)	D8120	150,000	LBS	$0.60	$90,000
		Cement (6sacks/CY)	D8120	4,300	TONS	$110.00	$473,000
		Install exposed portions of new 20-foot diameter	D8420	3,700	LF	$4,400.00	$16,280,000
		penstocks (740' ea.)					
		install @$1.00/lb @ 4390#/ft					
		SHEET G SUBTOTAL					$55,971,900

QUANTITIES		PRICES	
BY Anderson, Frisz	CHECKED	BY	CHECKED Craig A. Grush
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

POWER OUTLETS:
NEW POWERPLANT ON LEFT ABUTMENT (Sht 1 of 3)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION: SHASTA

FILE: C:\WKSHTS\SHSTA\SUM1280.WK4 H

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Excavation for new powerplant (rock)	D8120	1,540,000	CY	$15.00	$23,100,000
		Dewatering for new powerplant	D8120	1	LS	$1,200,000.00	$1,200,000
		(Assume 500 gpm for 1 year)					
		install + operate					
		Concrete in Substructure	D8120	36,800	CY	$350.00	$12,880,000
		Concrete in Intermediate Structure	D8120	28,700	CY	$400.00	$11,480,000
		Concrete in Superstructure	D8120	9,200	CY	$450.00	$4,140,000
		Concrete in Second Stage	D8120	24,000	CY	$350.00	$8,400,000
		Furnish and handle cement for new powerplant	D8120	28,000	TONS	$110.00	$3,080,000
		(6 sacks/CY)					
		Furnish and place reinforcement in new powerplant	D8120	10,850,000	LBS	$0.50	$5,425,000
		Structural Steel in Superstructure	D8120	750,000	LBS	$1.80	$1,350,000
		(crane beams/ rails, roof)					
		Miscellaneous metalwork for new powerplant	D8120	200,000	LBS	$4.50	$900,000
		(ladders, guardrails, catwalks, stairs, hatches)					
		Heating and ventilating for new powerplant	D8410	1	LS	$200,000.00	$200,000
		note[?]: 20 kW cap.					
		priced @ $5.00/sf for LB area only					
		Sanitary systems for new powerplant	D8410	1	LS	$120,000.00	$120,000
		priced @ $3.00/sf for LB area only					
		Lighting system for new powerplant	D8430	1	LS	$564,600.00	$564,600
		HB LIGHTING [MH or MV]		56,400	FT2	$6.50	
		LB LIGHTING [FLUR]		39,600	FT2	$5.00	
		Electrical system for new powerplant	D8430	1	LS	$192,000.00	$192,000
		COST/FT2	$2.00	excluding lights			
		SHEET H SUBTOTAL					$73,031,600 √

QUANTITIES		PRICES	
BY Anderson, LaFond	CHECKED	BY	CHECKED Craig A. Gush
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF_____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

POWER OUTLETS:
NEW POWERPLANT ON LEFT ABUTMENT (Sht 2 of 3)

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\WKSHTS\SHSTA\SUM1280.WK4 I

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		F&I five new turbines (260MW, 163.64 rpm,	D8420	6,700,000	LBS	$12.00	$80,400,000
		575' design head, 1,340,000 lbs/ea.)					
		G. Coulee new units					
		F&I five governors - 850,000 ft-lbs - 65,000 ea.	D8420	325,000	LBS	$10.00	$3,250,000
		F&I 2 Generator CO2 system - 15,500lbs/ea	D8420	31,000	LBS	$8.00	$248,000
		F&I Unit cooling water piping system, governor and	D8420	225,000	LBS	$8.00	$1,800,000
		lube oil piping system (5 at 45,000 lbs/ea)					
		F&I plant water piping and fire protection system	D8420	105,000	LBS	$6.00	$630,000
		(5 at 7,000 lbs/ea)					
		F&I transformer oil fire protection piping system	D8420	225,000	LBS	$6.00	$1,350,000
		(5 at 45,000 lbs/ea)					
		F&I compressed air piping system (5 at 7,000 lbs/ea)	D8420	35,000	LBS	$6.00	$210,000
		F&I exposed piping system (5 at 39,000 lbs/ea)	D8420	195,000	LBS	$6.00	$1,170,000
		F&I unwatering piping system (5 at 39,000 lbs/ea)	D8420	195,000	LBS	$4.00	$780,000
		F&I drainage piping system (5 at 36,000 lbs/ea)	D8420	180,000	LBS	$4.00	$720,000
		F&I two 500T overhead travelling cranes,	D8410	2	EA	$1,500,000	$3,000,000
		span=70 ft, (600,000 lbs/ea)					
		priced @ 2.50/lb - ref: Richardson					
		Furnishing and installing 15 kV SF6 power circuit	D8430	5	EA	$160,000	$800,000
		breaker, 12,5000 amp continous current, 105 kA					
		rms symm interupting (8 cycle) rating					
		Means: gas breakers					
		Furnishing and installing 260 MW, 0.95 PF	D8430	5	EA	$10,100,000	$50,500,000
		163.64 rpm, 13,800 volt, vertical synchronous					
		generator with static excitation system					
		SHEET I SUBTOTAL					$144,858,000

QUANTITIES		PRICES	
BY Zelenka, Ritt, Rossi	CHECKED	BY	CHECKED Craig A. Hinch
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF ______

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1280

POWER OUTLETS:
NEW POWERPLANT ON LEFT ABUTMENT (Sht 3 of 3)

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\WKSHTS\SHSTA\SUM1280.WK4 J

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Furnishing and installing 3 ph, 15 kV, 12,500 amp isolated phase bus	D8430	500	LF	$1,800	$900,000
		Furnishing and installing a 480-volt, 1200 amp double-ended station service switchgear assembly with 5 vertical sections	D8430	1	EA	$175,000	$175,000
		Furnishing and installing 600-volt motor control centers rated 800 amps with 5 vertical sections	D8430	5	EA	$60,000	$300,000
		Furnishing and installing duplex control switchboard with 12 sections	D8430	1	EA	$220,000	$220,000
		Furnishing and installing station service transformer rated 1500 kVA , 13.8 kV-277\480 V	D8430	2	EA	$35,000	$70,000
		Furnishing and installing 1-phase, outdoor oil-filled generator step up transformer rated 91 kVA, FOA, 230 kV Gnd Y/ 13.8 kV Delta, 825\110 kV BIL	D8440	16	EA	$10,000	$160,000
		SHEET J SUBTOTAL					$1,825,000 ✓
		SHEET A					$13,295,450 ✓
		SHEET B					$18,125,690 ✓
		SHEET C					$14,695,650 ✓
		SHEET D					$6,219,500 ✓
		SHEET E					$16,421,600 ✓
		SHEET F					$44,732,400 ✓
		SHEET G					$55,971,900 ✓
		SHEET H					$73,031,600 ✓
		SHEET I					$144,858,000 ✓
		SHEET J					$1,825,000 ✓
		TOTAL					$389,176,790

QUANTITIES		PRICES	10:26 AM
BY Rossi	**CHECKED**	**BY** L. PEDDE	**CHECKED** Craig A. Gush
DATE PREPARED 2-2-98	**APPROVED**	**DATE** 02/12/98	**PRICE LEVEL** APP.

CODE: D 8170

ESTIMATE WORKSHEET

FEATURE:
SHASTA DAM ENLARGEMENT
EL 1280: **COST SUMMARY**

WOID: SHDES

PROJECT:
DIVISION / REGION: MP
CONTRACT/SPEC:
FILE: C:\WKSHTS\SHSTA\SUM1280.WK4

10:37 AM

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		POWERPLANT STRUCTURES					
		FILE: SHAS1280.WK4					
		LINKED FILE DATA					
		FILE SUBTOTAL					$389,176,790.00 ✓
		MOBILIZATION	+/-	5.0%			$19,500,000.00 ✓
		SUBTOTAL					$408,676,790.00 ✓
		UNLISTED	+/-	15.0%			$61,323,210.00 ✓
		ESTIMATED CONTRACT COST					$470,000,000.00 ✓
		CONTINGENCIES	+/-	25.0%			$120,000,000.00 ✓
		EST. FIELD COST					$590,000,000.00 ✓

QUANTITIES		PRICES	
BY	APPROVED	BY L Pedde L. PEDDE	CHECKED Craig A. Gusk
DATE PREPARED	DATE	DATE 12-Feb-98	PRICE LEVEL

CODE:D-3521

ESTIMATE WORKSHEET

FEATURE: 05-Feb-98

SHASTA POWER PLANT
230/525 KV SWITCHYARD
EL. 1280

PROJECT: CENTRAL VALLEY

DIVISION: CIVIL ENGINEERING

UNIT: D-8120

FILE: A:\SHDES128.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		NEW SWITCHYARD:					
		Furnishing and erecting takeoff structures		99,000	lb	$2.50	$247,500.00
		Furnishing and erecting switchyard supports		560,000	lb	$2.10	$1,176,000.00
		Excavation for switchyard foundations		278,000	cu. yd	$4.50	$1,251,000.00
		Placing and compacting backfill		273,000	cu. yd	$7.50	$2,047,500.00
		Furnishing and placing 6" gravel surfacing		51,000	sq yd	$6.50	$331,500.00
		Furnishing and placing gravel for gravelfills		3,800	cu. yd	$30.00	$114,000.00
		Furnishing and applying soil-applied herbicide		51,000	sq. yd	$0.65	$33,150.00
		Furnishing and placing concrete in switchyard foundations		5,400	cu. yd	$350.00	$1,890,000.00
		Furnishing and handling cementitous materials		1,523	tons	$115.00	$175,145.00
		Furnishing and placing reinforcing bars in switchyard foundations		920,000	lb	$0.70	$644,000.00

QUANTITIES		PRICES	
BY: Gerald Sherard	CHECKED	BY: L.PEDDE	CHECKED: Craig A. Gusk
DATE PREPARED: January 16,1998	APPROVED	DATE: 05-Feb-98	PRICE LEVEL APPR

CODE:D-3521

ESTIMATE WORKSHEET

SHEET 2 OF 2

FEATURE: 05-Feb-98

SHASTA POWER PLANT
230/525 KV SWITCHYARD
EL. 1280

PROJECT: CENTRAL VALLEY

DIVISION: CIVIL ENGINEERING

UNIT: D-8120

FILE: A:\SHDES128.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Furnishing and erecting 7-foot-high chain link fence		3,300	ft	$24.00	$79,200.00
		Furnishing and installing oil containment system		1	ls	$60,000.00	$60,000.00
		DEMOLITON OF OLD SWITCHYARD:					
		Remove lattice steel structures		1,000,000	lb	$0.25	$250,000.00
		Remove concrete foundations		6,000	cu. yd	$200.00	$1,200,000.00
		(Excavation and embankment covered under new power plant construction on old switchyard site)					
		SUBTOTAL					$9,498,995.00

QUANTITIES		PRICES	
BY Gerald Sherard		BY L.PEDDE	CHECKED Craig A. Gusk
DATE PREPARED January 16, 1998	APPROVED	DATE 05-Feb-98	PRICE LEVEL APPR

ESTIMATE WORKSHEET

CODE: D 8170

SHEET 1 OF

FEATURE: Elev 1280 - Alt A2
230/525 kV Swyd
Existing PP & New PP

WOID: SHDES

PROJECT: SHASTA DAM ENL.
DIVISION / REGION: MP
CONTRACT/SPEC:
FILE: A:\EST_3SH.WK4

12:02 PM

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	3Ø Gang Oper 550 kV Disc Sw, 3,000 A Cont, 64 kA Momentary	D8440	14	ea	$75,000.00	$1,050,000.00
	2	3Ø Gang Oper 242 kV Disc Sw, 3,000 A Cont,100 kA Momentary	D8440	51	ea	$30,000.00	$1,530,000.00
	3	550 kV Circuit Breaker, 3,000 A Cont, 40 kA Int Rat, 2 Cyc Int Time, 1,800 kV BIL	D8440	5	ea	$750,000.00	$3,750,000.00
	4	242 kV Circuit Breaker, 3,000 A Cont, 63 kA Int Rat, 3 Cyc Int Time, 900 kv BIL	D8440	18	ea	$200,000.00	$3,600,000.00
	5	335 kV MCOV, Station Class Surge Arrester	D8440	6	ea	$8,500.00	$51,000.00
	6	156 kv MCOV, Station Class Surge Arrester	D8440	30	ea	$6,600.00	$198,000.00
	7	1Ø -400,000/532,000 kVA FOA 525 GrdY / 230 GrdY / 13.8 kV, 1425 / 750 / 110 kV BIL, 35% Tert Rating Power Transformer	D8440	7	ea	$8,000,000.00	$56,000,000.00
	8	4/0 Copper Ground Cable for 230 kV Swyd	D8440	20,000	ft	$7.50	$150,000.00
	9	4/0 Copper Ground Cable for 500 kV Swyd	D8440	14,000	ft	$7.50	$105,000.00
	10	Copper Ground Rods for 230 kV & 525 kV Swyds	D8440	500	ea	$100.00	$50,000.00
	11	6" Rigid Alum Bus (230 kV Swyd)	D8440	5,000	feet	$100.00	$500,000.00
	12	3" Rigid Alum Bus (525 kV Swyd)	D8440	2,500	feet	$40.00	$100,000.00
	13	Misc Alum Bus Conn (230 kV & 525 kV Swyd)	D8440	1	LS	$50,000.00	$50,000.00
	14	Misc Conduit (230 kV & 525 kV Swyd)	D8440	1	LS	$50,000.00	$50,000.00
	15	Removal of 40 ea 230 kv air switches, 9 ea 230 kV circuit breakers, and misc BTs, PTs, surge arresters etc. from the existing switchyard.	D8440	1	LS	$15,000.00	$15,000.00
		SHEET SUBTOTAL					$67,199,000.00 ✓

QUANTITIES		PRICES	
BY T. Williams	APPROVED	BY L. PEDDE	CHECKED Craig A. Hursh
DATE PREPARED Jan 30, 98	DATE	DATE 09-Feb-98	PRICE LEVEL APPRAISAL

CODE: D 8170

ESTIMATE WORKSHEET

SHEET 1 OF 2

FEATURE:
SHASTA DAM ENLARGEMENT
EL 1280: **COST SUMMARY**

WOID: SHDES

PROJECT:
DIVISION / REGION: MP
CONTRACT/SPEC:
FILE: C:\WKSHTS\SHSTA\SUM1280.WK4

10:37 AM

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		SWITCHYARD - CIVIL					
		FILE: SHDES128.WK4					
		LINKED FILE DATA					
		FILE SUBTOTAL					$9,498,995.00 ✓
		MOBILIZATION	+/-	5.0%			$450,000.00 ✓
		SUBTOTAL					$9,948,995.00
		UNLISTED	+/-	15.0%			$1,451,005.00 ✓
		ESTIMATED CONTRACT COST					$11,400,000.00 ✓
		CONTINGENCIES	+/-	25.0%			$2,900,000.00
		EST. FIELD COST					$14,300,000.00 ✓
		SWITCHYARD - ELECTRICAL					
		FILE: EST_3SH.WK4					
		LINKED FILE DATA					
		FILE SUBTOTAL					$67,199,000.00 ✓
		MOBILIZATION	+/-	5.0%			$3,400,000.00 ✓
		SUBTOTAL					$70,599,000.00
		UNLISTED	+/-	15.0%			$10,401,000.00 ✓
		ESTIMATED CONTRACT COST					$81,000,000.00 ✓
		CONTINGENCIES	+/-	25.0%			$19,000,000.00
		EST. FIELD COST					$100,000,000.00

QUANTITIES		PRICES	
BY	APPROVED	BY L. Pedde L. PEDDE	CHECKED Craig a. Gusch
DATE PREPARED	DATE	DATE 12-Feb-98	PRICE LEVEL

CODE:CE 3323

ESTIMATE WORKSHEET

FEATURE:

Shasta Lake Enlargement
Relocation for Elevation 1280 feet

PROJECT: Central Valley

DIVISION:

FILE:

DESCRIPTION	QUANTITY	CONTRACT COST JAN. 82	FIELD COST JAN. 82 (Contingencies +/- 25%)	USBR INDEX JAN. 82	USBR INDEX OCT. 97	AMOUNT
Resort Location and Land Rights	LS	$40,000,000	$50,000,000	144	222	$77,000,000
Public Recreation Relocation	LS	$108,000,000	$135,000,000	144	222	$210,000,000
Reservoir Clearing	30500	$1,200	$46,000,000			$46,000,000
Enlarged Keswick Dam	LS	$40,000,000	$50,000,000	153	208	$68,000,000
Enlarged Keswick Dam Powerplant (1)	LS	$143,345,600	$180,000,000	219	224	$185,000,000
Recreation Facilities	LS	$29,600,000	$37,000,000	144	222	$57,000,000
Sacramento River Seepage Mitigation	LS	$44,800,000	$56,000,000	144	222	$86,000,000
Subtotal 1						$729,000,000

(1) Contract cost from October 1996

QUANTITIES		PRICES	
BY From sheets provided by T. Hepler	CHECKED	BY Craig Grush	CHECKED [signature] 2/12/98
DATE PREPARED	APPROVED	DATE 12-Feb-98	PRICE LEVEL

CODE:CE 3323

ESTIMATE WORKSHEET

FEATURE:

Shasta Lake Enlargement
Relocation for Elevation 1280 feet

PROJECT: Central Valley

DIVISION:

FILE:

DESCRIPTION	QUANTITY	CONTRACT COST APR. 84	FIELD COST APR. 84 (Contingencies +/- 25%)	USBR INDEX APR. 84	USBR INDEX OCT. 97	AMOUNT
Southern Pacific Railroad Relocation (APR 84)						
Earthwork	LS	$91,500,000	$115,000,000	154	224	$165,000,000
Railroad	LS	$38,300,000	$48,000,000	154	224	$70,000,000
Bridges	LS	$53,300,000	$67,000,000	155	232	$100,000,000
Tunnels	LS	$67,100,000	$84,000,000	161	234	$120,000,000
I-5 Relocation (APR 84)						
Earthwork	LS	$57,500,000	$72,000,000	154	224	$105,000,000
Railroad	LS	$22,700,000	$28,000,000	154	224	$41,000,000
Bridges	LS	$43,500,000	$54,000,000	155	232	$81,000,000
Interchanges	LS	$3,750,000	$4,700,000	154	224	$6,800,000
Land Acquisition	LS	$700,000	$880,000	155	222	$1,250,000
Subtotal 2						$690,050,000
Total (Subtotal 1 + Subtotal 2)						$1,419,050,000

QUANTITIES		PRICES	
BY INFO. FROM T. HEALER	CHECKED	BY Craig Grush	CHECKED [signature] 2/12/98
DATE PREPARED	APPROVED	DATE 12-Feb-98	PRICE LEVEL

CODE:D-8170

APPENDIX D-2 **ESTIMATE WORKSHEET**

SHEET 1 OF 2

FEATURE:	**PROJECT:**
20-Feb-98	CENTRAL VALLEY PROJECT
SHASTA DAM ENLARGEMENT - EL. 1180	**DIVISION:**
Dam Enlargement and Structures	**FILE:** C:\123R4D\EST\SHASTA~1\TOTL1180.WK4 — **REVISION: 01**
Appraisal Level Est. - Jan. 98	

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Cofferdams for Left and Right Abutments			ls		$29,000,000
	2	Removal of Structures for Concrete Dam Raise			ls		$11,000,000
	3	Concrete Dam and RCC Wing Dam			ls		$550,000,000
	4	Spillway			ls		$17,500,000
	5	River Outlet Works			ls		$58,000,000
	6	Dikes			ls		$28,900,000
		Dike # 3 - Jones Valley Dike		$20,000,000			
		Dike # 4 - Clickapudi Dike		$8,900,000			
	7	New Power Plant and Modifications to Existing Power Plant					$530,000,000
	8	230/ 525 - kv Switchyard					
		Electrical					$50,000,000
		Civil					$10,300,000
				SUBTOTAL SHEET 1 of 2			$1,284,700,000

QUANTITIES		PRICES	
BY T Hepler	CHECKED	BY: R. Baumgarten, L. Pedde K.Copeland, C. Grush	CHECKED Craig A. Grush
DATE PREPARED	APPROVED	DATE 02/20/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 2 OF 2

FEATURE:	PROJECT:
SHASTA DAM ENLARGEMENT - EL. 1180 (20-Feb-98)	CENTRAL VALLEY PROJECT
Relocation Cost Sheet	DIVISION:
Appraisal Level Est. - Jan. 98	FILE: C:\123R4D\EST\SHASTA~1\TOTL1180.WK4 — REVISION: 01

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Resort Location and Land Rights			ls		$59,000,000
		Public Recreation Relocation			ls		$210,000,000
		Reservoir Clearing			ls		$24,000,000
		Recreation Facilities			ls		$48,000,000
		Sacramento River Seepage Mitigation			ls		$43,000,000
		Bridge Bay Crossing (1)			ls		$340,000,000
		Southern Pacific Railroad Relocation (APR 84)					
		Earthwork			ls		$130,000,000
		Railroad			ls		$54,000,000
		Bridges			ls		$76,000,000
		Tunnels			ls		$93,000,000
		I-5 Relocation (APR 84)					
		Earthwork			ls		$80,000,000
		Roadway			ls		$32,000,000
		Bridges			ls		$63,000,000
		Interchanges			ls		$5,200,000
		Land Acquisition			ls		$990,000
	Note:	Relocation costs indexed from sheet provided by Tom Hepler. Most of the relocation costs have been indexed from Jan.82/Apr.84 to Oct. 1997 using BOR Construction Cost Indexes. We do not recommend indexing costs for more than a five year span. All relocation costs that have been indexed greater than 5 years should be recomputed using 1998 costs.		SUBTOTAL SHEET 2	of 2		$1,258,190,000
				SUBTOTAL SHEET 1	of 2		$1,284,700,000
						TOTAL	$2,542,890,000
		(1) - Provided by others than D8170					

QUANTITIES		PRICES	
BY: T Hepler	CHECKED	BY: R. Baumgarten, L. Pedde, K.Copeland, C. Grush	CHECKED: Craig A. Grush
DATE PREPARED	APPROVED	DATE: 02/20/98	PRICE LEVEL: Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 13-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1180

COFFERDAMS FOR LEFT AND RIGHT ABUTMENTS

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHS21180.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$1,000,000
	2	Diversion and care of releases during construction	D8130	Lump sum	ls		$4,500,000
	3	Removal and control of water during construction	D8130	Lump sum	ls		$750,000
	4	Excavation for cellular cofferdams, embankment (dr	D8130	275,000	yd3	$3.00	$825,000
	5	Excavation for cellular cofferdams, rock (dry)	D8130	25,000	yd3	$8.00	$200,000
	6	Furnish and install steel sheet piling, PSX-32	D8130	5,100	tons	$1,200.00	$6,120,000
	7	Furnish and place free-draining fill materials	D8130	185,000	yd3	$12.00	$2,220,000
	8	Concrete in anchor blocks	D8130	4,200	yd3	$85.00	$357,000
	9	Backfill concrete on foundation and abutments	D8130	16,000	yd3	$75.00	$1,200,000
	10	Furnishing and handling cement	D8130	3,300	tons	$100.00	$330,000
	11	Furnishing and handling pozzolan	D8130	830	tons	$60.00	$49,800
	12	Removal of steel sheet piling in cofferdams	D8130	5,100	tons	$600.00	$3,060,000
	13	Removal of free-draining fill materials	D8130	185,000	yd3	$4.00	$740,000
		Subtotal					**$21,351,800**
		Unlisted items @ 10 percent					**$1,648,200**
		Contract cost					**$23,000,000**
		Contingencies @ 25 percent					**$6,000,000**
		Field cost					**$29,000,000**

QUANTITIES		PRICES	
BY R. Benik	CHECKED T. Hepler	BY K. Copeland KS	CHECKED Craig A. Gush
DATE PREPARED 02/06/98	APPROVED	DATE 02/13/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1180

REMOVAL OF STRUCTURES FOR CONCRETE DAM RAISE

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHST1180.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$380,000
	2	Removal of gantry crane and rails from dam crest	D8410	841,000	lbs	$0.30	$252,300
	3	Removal of spillway drum gates and frames	D8420	3,255,000	lbs	$0.60	$1,953,000
	4	Removal of drum gate control equipment	D8420	90,000	lbs	$0.75	$67,500
	5	Removal of structural steel in spillway bridge		976,000	lbs	$0.30	$292,800
	6	Removal of freight and passenger elevators	D8410	Lump sum	ls		$100,000
	7	Removal of concrete in spillway bridge and piers	D8130	2,800	yd3	$150.00	$420,000
	8	Removal of concrete in parapets and crest cantilever	D8130	5,730	yd3	$300.00	$1,719,000
	9	Removal of concrete in spillway crest	D8130	3,530	yd3	$200.00	$706,000
	10	Removal of concrete in spillway training walls	D8130	8,340	yd3	$150.00	$1,251,000
	11	Removal of concrete in spillway stilling basin	D8130	1,210	yd3	$80.00	$96,800
	12	Removal of concrete in hoist and elevator towers	D8130	1,500	yd3	$250.00	$375,000
	13	Removal of misc. concrete on both abutments	D8130	820	yd3	$50.00	$41,000
	14	Removal of left abutment concrete core wall during embankment excavation	D8130	6,100	yd3	$50.00	$305,000
		Subtotal					**$7,959,400**
		Unlisted items @ 10 percent					**$840,600**
		Contract cost					**$8,800,000**
		Contingencies @ 25 percent					**$2,200,000**
		Field cost					**$11,000,000**

QUANTITIES		PRICES	
BY: R. Benik	CHECKED: T. Hepler	BY: R. Baumgarten	CHECKED: Craig A. Gush
DATE PREPARED: 02/06/98	APPROVED:	DATE: 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 2

FEATURE: 13-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1180

CONCRETE DAM AND RCC WING DAMS

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHST1180.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$35,000,000
	2	Excavation, open-cut, all classes (dry)	D8130	1,500,000	yd3	$6.50	$9,750,000
	3	Excavation for grouting and drainage tunnels	D8130	1,250	yd3	$250.00	$312,500
	4	Deleted					
	5	Furnish and install rock bolts (1-inch diameter)	D8130	6,000	lft	$25.00	$150,000
	6	Furnish and apply 6" shotcrete tunnel support	D8130	1,600	yd2	$50.00	$80,000
	7	Cleanup for foundation inspection	D8130	37,000	yd2	$9.00	$333,000
	8	Drilling foundation grout holes (A- and B-holes)	D8130	94,000	lft	$28.00	$2,632,000
	9	Furnishing, mixing, and pressure grouting foundatio	D8130	70,000	bags	$18.00	$1,260,000
	10	Drilling foundation drain holes from galleries	D8130	55,000	lft	$30.00	$1,650,000
	11	Constructing 5" and 18" formed drains in dam	D8130	50,000	lft	$28.00	$1,400,000
	12	Furnishing and installing flat drains at dam contact	D8130	44,000	lft	$10.00	$440,000
	13	Shaping and dental concrete	D8130	80,000	yd3	$90.00	$7,200,000
	14	Mass concrete in dam (10-foot lifts)	D8130	2,600,000	yd3	$82.00	$213,200,000
	15	Roller-compacted concrete in wing dams	D8130	580,000	yd3	$29.00	$16,820,000
	16	Concrete in slip-formed facing elements	D8130	32,000	yd3	$175.00	$5,600,000
	17	Concrete in crest cantilever	D8130	15,400	yd3	$200.00	$3,080,000
	18	Concrete in sidewalks and parapet walls	D8130	1,820	yd3	$350.00	$637,000
	19	Concrete in elevator and hoist towers	D8130	1,500	yd3	$600.00	$900,000

QUANTITIES		PRICES	
BY R. Benik	CHECKED T. Hepler	BY R. Baumgarten	CHECKED Craig a. Lusk
DATE PREPARED 02/11/98	APPROVED	DATE 02/13/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 13-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1180

CONCRETE DAM AND RCC WING DAMS (CONT.)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHST1180.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	20	Concrete in grouting and drainage tunnel floors	D8130	200	yd3	$250.00	$50,000
	21	Furnishing and handling cement	D8130	396,000	tons	$92.00	$36,432,000
	22	Furnishing and handling pozzolan	D8130	203,000	tons	$55.00	$11,165,000
	23	Temperature control of mass concrete	D8130	2,600,000	yd3	$6.50	$16,900,000
	24	Furnishing and placing metal pipe for temp. control	D8130	1,200,000	lft	$5.00	$6,000,000
	25	Furnishing and placing metal pipe for grouting contraction joints in dam	D8130	280,000	lbs	$3.00	$840,000
	26	Furnishing, mixing, and pressure grouting contractio joints and temperature control systems in dam	D8130	20,000	bags	$15.00	$300,000
	27	Furnishing and installing 12-inch PVC waterstop	D8130	90,000	lft	$10.00	$900,000
	28	Furnishing and placing reinforcing bars	D8130	2,500,000	lbs	$0.50	$1,250,000
	29	Furnishing and installing instrumentation	D8130	Lump sum	ls		$5,300,000
	30	Furnishing and installing two elevators	D8410	Lump sum	ls		$840,000
	31	Gantry crane and rails, 125 ton, right side	D8410	605,000	lbs	$3.00	$1,815,000
	32	Gantry crane and rails, 175 ton, left side	D8410	705,000	lbs	$3.00	$2,115,000
	33	Ventilating systems for RCC galleries (10kw sys.)	D8130	12,600	sf	$5.00	$63,000
	34	Lighting systems for dam and galleries (82kw sys.)	D8130	150,000	sf	$6.50	$975,000
		Subtotal					**$385,389,500**
		Unlisted items @ 15 percent					**$54,610,500**
		Contract cost					**$440,000,000**
		Contingencies @ 25 percent					**$110,000,000**
		Field Cost					**$550,000,000**

QUANTITIES		PRICES	
BY R. Benik	CHECKED T. Hepler	BY R. Baumgarten	CHECKED Craig A. Yursh
DATE PREPARED 02/11/98	APPROVED	DATE 02/13/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1180

SPILLWAY

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHST1180.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$610,000
	2	Concrete in spillway training walls on d/s face	D8130	4,100	yd3	$350.00	$1,435,000
	3	Concrete in spillway bridge piers	D8130	5,700	yd3	$250.00	$1,425,000
	4	Concrete in spillway bridge and operating deck	D8130	1,400	yd3	$600.00	$840,000
	5	Furnishing and handling cement	D8130	2,500	tons	$110.00	$275,000
	6	Furnishing and handling pozzolan	D8130	650	tons	$65.00	$42,250
	7	Furnishing and placing reinforcing bars	D8130	1,500,000	lbs	$0.55	$825,000
	8	Six spillway radial gates, 55 by 27.5 feet	D8420	1,155,000	lbs	$3.00	$3,465,000
	9	Six sets, embedded metalwork for radial gates	D8420	284,000	lbs	$3.50	$994,000
	10	Six radial gate hoists, 164,000 lb capacity each	D8410	295,200	lbs	$7.00	$2,066,400
	11	Gantry crane and rails, 60 ton capacity	D8410	246,000	lbs	$3.50	$861,000
		Subtotal					**$12,838,650**
		Unlisted items @ 10 percent					**$1,161,350**
		Contract cost					**$14,000,000**
		Contingencies @ 25 percent					**$3,500,000**
		Field cost					**$17,500,000**

QUANTITIES		PRICES	
BY T. Hepler	CHECKED	BY R. Baumgarten	CHECKED Craig A. Lush
DATE PREPARED 02/09/98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 2

FEATURE: 13-Feb-98

SHASTA DAM
ENLARGEMENT - EL. 1180

RIVER OUTLETS

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHS21180.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$2,000,000
	2	Removal of eighteen coaster gate frames, u/s face		1,090,000	lbs	$0.80	$872,000
	3	Removal of eight 96-inch outlet gates	D8420	1,040,000	lbs	$0.35	$364,000
	4	Removal of four 102-inch tube valves	D8420	1,032,000	lbs	$0.35	$361,200
	5	Removal of steel liners for outlets (740 lin ft)	D8420	500,000	lbs	$0.50	$250,000
	6	Removal of gate and valve operating systems	D8420	36,000	lbs	$0.75	$27,000
	7	Excavation of concrete for 12 new gate chambers	D8130	1,910	yd3	$450.00	$859,500
	8	Concrete in 12 new gate chambers	D8130	1,750	yd3	$350.00	$612,500
	9	Furnishing and handling cement	D8130	400	tons	$110.00	$44,000
	10	Furnishing and handling pozzolan	D8130	100	tons	$70.00	$7,000
	11	Furnishing and placing reinforcing bars	D8130	260,000	lbs	$0.60	$156,000
	12	One 11- by 11-foot bulkhead gate, 440-ft head	D8420	132,000	lbs	$4.00	$528,000
	13	Bulkhead gate guides for 18 outlets, u/s face	D8420	1,300,000	lbs	$3.50	$4,550,000
	14	Bulkhead gate lifting frame	D8420	5,000	lbs	$3.00	$15,000
	15	Eight 102-inch ring-follower gates, 440-ft head	D8420	1,328,000	lbs	$6.50	$8,632,000
	16	Sixteen 102-inch ring-follower gates, 340-ft head	D8420	2,592,000	lbs	$6.50	$16,848,000
	17	Control systems for 24 gates	D8420	72,000	lbs	$18.00	$1,296,000
	18	Furnish and install 102-inch steel liners for outlets	D8420	1,500,000	lbs	$2.75	$4,125,000

QUANTITIES		PRICES	
BY J. Ellingson	CHECKED T. Hepler	BY K. Copeland R. Baumgarten	CHECKED Craig a. Gush
DATE PREPARED 02/09/98	APPROVED	DATE 02/13/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 13-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1180

RIVER OUTLETS (CONT.)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHS21180.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	19	Backfill grouting for 102-inch steel liners (540 lin ft)	D8420	8,000	bags	$20.00	$160,000
	20	Extend 36-inch steel piping for air vents (El. 988)	D8420	14,000	lbs	$10.00	$140,000
	21	Furnish and install air valves and filling lines	D8420	2,000	lbs	$15.00	$30,000
		Subtotal					**$41,877,200**
		Unlisted items @ 10 percent					**$4,122,800**
		Contract cost					**$46,000,000**
		Contingencies @ 25 percent					**$12,000,000**
		Field cost					**$58,000,000**

QUANTITIES		PRICES	
BY J. Ellingson	CHECKED T. Hepler	BY K. Copeland R. Baumgarten	CHECKED Craig A. Gush
DATE PREPARED 02/06/98	APPROVED	DATE 02/13/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 11-Feb-98

SHASTA DAM ENLARGEMENT
JONES VALLEY DIKE - R. EL 1180
DIKE No. 3

PROJECT:
CENTRAL VALLEY , CALIFORNIA

DIVISION:

FILE:
C:\123R4D\EST\SHASTA~1\TORRESDK.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization			L.S		$700,000
	2	Clearing and grubbing 6" to waste		105,000	S Y	$1.50	$157,500
	3	**Foundation treatment**					
		Surface excavation		38,700	CY	$5.00	$193,500
		Core trench excavation		62,970	CY	$7.00	$440,790
		Pipe for grouting w/fittings,3.5' x2"Dia.		252	EA	$50.00	$12,600
		Drill Setup for Grout holes		252	EA	$100.00	$25,200
		Drilling grout holes, 40'		13,600	L F	$30.00	$408,000
		Casing grout holes (Assume 10%)		1,360	L F	$12.00	$16,320
		Hookups for grout holes		252	EA	$50.00	$12,600
		Pressure grouting		13,600	BAGS	$8.00	$108,800
		Cement for pressure grouting		13,600	BAGS	$7.00	$95,200
		Water tests		504	EA	$65.00	$32,760
		Slush grout		38,700	S Y	$13.00	$503,100
		Dental concrete		100	CY	$250.00	$25,000
	4	Exc. (5 mi haul), placement and compaction zone 1		425,800	C Y	$8.00	$3,406,400
	5	Exc. (5 mi haul), placement and compaction zone 2		626,200	C Y	$7.50	$4,696,500
	6	Chimney drain and drainage blanket (assume borrow)		68,600	C Y	$25.00	$1,715,000
	7	Riprap (assume borrow)		31,500	C Y	$30.00	$945,000
	8	Riprap bedding (assume borrow)		15,800	C Y	$25.00	$395,000
	9	**Toe drain**					
		Excavation		18,700	C Y	$6.50	$121,550
		Drain material		18,750	C Y	$27.00	$506,250
		Perforated PVC 12" pipe		1,260	L F	$35.00	$44,100
		Weir Box		1	EA	$5,000.00	$5,000
	7	Instrumentation		1	LS		$160,000
		Subtotal					$14,726,170
		Unlisted items (10%)					$1,273,830 ✓
		Contract cost					$16,000,000 ✓
		Contingencies (25%)					$4,000,000
		Field Cost					$20,000,000

QUANTITIES		PRICES	
BY R.L. Torres	CHECKED R. L. Webb	BY R. Baumgarten	CHECKED Craig A. Gusk
DATE PREPARED Feb. 4, 1998	APPROVED	DATE 02/11/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE:
SHASTA DAM ENLARGEMENT
CLICKAPUDI DIKE - R. EL 1180
DIKE No. 4

11-Feb-98

PROJECT: CENTRAL VALLEY , CALIFORNIA

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\TORRESDK.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization			L.S		$310,000
	2	Clearing and grubbing 6" to waste		54,200	S Y	$1.50	$81,300
	3	**Foundation treatment**					
	3.a	Surface excavation		25,720	CY	$6.00	$154,320
	3.b	Core trench excavation		25,600	CY	$7.00	$179,200
	3.c	Pipe for grouting w/fittings,3.5' x2"Dia.		140	EA	$60.00	$8,400
	3.d	Drill Setup for Grout holes		140	EA	$110.00	$15,400
	3.e	Drilling grout holes, 40' deep, each		12,800	L F	$30.00	$384,000
	3.f	Casing grout holes (Assume 10%)		1,280	L F	$12.00	$15,360
	3.g	Hookups for grout holes		140	EA	$70.00	$9,800
	3.h	Pressure grouting		5,600	BAGS	$9.00	$50,400
	3.i	Cement for pressure grouting		5,600	BAGS	$7.50	$42,000
	3.j	Water tests		280	EA	$70.00	$19,600
	3.k	Slush grout		25,720	S Y	$14.00	$360,080
	3.1	Dental concrete		100	CY	$250.00	$25,000
	4	Exc.(5 mi. haul), placement and compaction zone 1		153,500	C Y	$8.50	$1,304,750
	5	Exc.(5 mi. haul), placement and compaction zone 2		210,500	C Y	$8.00	$1,684,000
	6	Chimney drain and drainage blanket (assume borrow)		26,700	C Y	$28.00	$747,600
	7	Riprap (assume borrow)		11,870	C Y	$35.00	$415,450
	8	Riprap bedding (assume borrow)		6,000	C Y	$30.00	$180,000
	6	**Toe drain**					
		Excavation		10,400	C Y	$7.00	$72,800
		Drain material		10,400	C Y	$32.00	$332,800
		Perforated PVC 12" pipe		700	L F	$37.00	$25,900
		Weir Box		1	EA	$5,000.00	$5,000
	7	Instrumentation		1	LS		$70,000
		Subtotal					**$6,493,160** ✓
		Unlisted items (10%)					**$606,840** ✓
		Contract cost					**$7,100,000** ✓
		Contingencies (25%)					**$1,800,000** ✓
		Field Cost					**$8,900,000** ✓

QUANTITIES		PRICES	
BY R.L. Webb	CHECKED R. L. Torres	BY R. Baumgarten	CHECKED Craig A. Grush
DATE PREPARED Feb. 4, 1998	APPROVED	DATE 02/11/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE:	12-Feb-98	PROJECT:	09:16 AM
SHASTA DAM ENLARGEMENT *EL. 1180*		CENTRAL VALLEY PROJECT	
POWER OUTLETS: MODIFICATIONS TO EXISTING TEMPERATURE CONTROL DEVICE		DIVISION: SHASTA	
		FILE: C:\WKSHTS\SHSTA\SHAS1180.WK4	A

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Remove existing 17 TCD gate hoists	D8410	884,000	LBS	$0.25	$221,000
		Remove existing electrical control equipment	D8430	1	LS	$5,200.00	$5,200
		(5 MCCs, 1 Distribution switchboard)					
		Remove existing miscellaneous metalwork	D8120	175,000	LBS	$0.30	$52,500
		Remove existing structural steel at El. 1067.5	D8120	750,000	LBS	$0.25	$187,500
		F&I new trashrack panels in the dry at El. 1067.5	D8410	477,000	LBS	$2.50	$1,192,500
		F&I new structural steel trashrack support structure in dry at El. 1067.5	D8120	630,700	LBS	$2.50	$1,576,750
		F&I new structural steel hoist support structure in dry at El. 1275.0	D8120	1,180,000	LBS	$2.00	$2,360,000
		F&I 17 new TCD gate hoists (150,000 lbs. cap.)	D8410	900,000	LBS	$7.00	$6,300,000
		F&I new miscellaneous metalwork at El. 1275.0	D8120	200,000	LBS	$5.00	$1,000,000
	*	F&I new electrical control equipment	D8430	1	LS	$400,000.00	$400,000
		(5 MCCs, 1 Distribution switchboard, conduit)					
		(Assume quantities are same as original TCD est.)					
		SHEET A SUBTOTAL					$13,295,450 ✓

QUANTITIES		PRICES	
BY LaFond, Christensen, Ritt	CHECKED	BY L. PEDDE	CHECKED Craig A. Lush
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL APPR.

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1180

POWER OUTLETS:
MODIFICATIONS TO EXISTING PENSTOCK INTAKES

PROJECT: CENTRAL VALLEY PROJECT

DIVISION: SHASTA

FILE: C:\WKSHTS\SHSTA\SHAS1180.WK4 B

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Remove existing gate hoist structure to El. 1068.75	D8110	125	CY	$200.00	$25,000
		Remove existing misc. metalwork	D8110	8,800	LBS	$0.30	$2,640
		Remove 5 existing coaster gates and operators	D8420	1	LS	$250,000.00	$250,000
		assuming approx. 1M lbs					
		Remove 5 exist. coaster gate frames btwn El. 803 and	D8420	562,000	LBS	$0.25	$140,500
		827 (Assume stoplogs allow work in dry)					
		Plug control rooms and stairs to 1065 gallery w/conc.	D8110	100	CY	$250.00	$25,000
		Extend existing gate hoist structure from El 1068.75					
		to El. 1280.0:					
		a. Reinforced Concrete	D8120	1,700	CY	$350.00	$595,000
		b. Reinforcement (120LBS/CY)	D8120	204,000	LBS	$0.60	$122,400
		c. Cement (6sacks/CY)	D8120	480	TONS	$110.00	$52,800
		F&I miscellaneous metalwork (hatches, grating)	D8120	10,000	LBS	$4.00	$40,000
		F&I 5 new wheel-mounted gates, H=473', (16'x25')	D8420	1,080,000	LBS	$2.50	$2,700,000
		F&I 5 hoists for wheel-mounted gates	D8420	633,000	LBS	$7.00	$4,431,000
		F&I 5 control systems for wheel-mounted gates	D8430	15,000	LBS	$15.00	$225,000
		F&I new gate guides and frames	D8420	843,000	LBS	$3.50	$2,950,500
		Furnish 1 set of new stoplogs (El. 797.59 - El. 1175)	D8410	1,685,000	LBS	$2.00	$3,370,000
		Furnish 1 stoplog lifting frame	D8410	4,500	LBS	$2.00	$9,000
		F&I cast steel stoplog guides - El. 1077.5 to El. 11175	D8410	200,000	LBS	$2.50	$500,000
		F&I electrical system for gate operation	D8430	1	LS	$75,000.00	$75,000
		SHEET B SUBTOTAL					$15,513,840

QUANTITIES		PRICES	
BY LaFond, Arrington, Christensen	CHECKED	BY	CHECKED Craig A. Kuch
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1180

**POWER OUTLETS:
MODIFICATIONS TO EXISTING
PENSTOCKS (sht 1 of 2)**

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\WKSHTS\SHSTA\SHAS1180.WK4 C

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Excavate five 17-foot diameter tunnels through dam	D8110	1	LS	$1,352,000.00	$1,352,000
		along existing 15-foot diameter penstocks to					
		remove existing penstocks (5x250) = 1,250 FT					
		(Intake El. 815, Use new stoplogs					
		on upstream face as temporary bulkhead)					
		(Rebar and steel supports will be encountered).					
		(Weight of penstock to be removed= 2,220,000 LBS)		2,220,000	LB	$0.35	
		(Volume of concrete to be removed= 2,300 CY)		2,300	CY	$250.00	
		Furnish five new 15-foot diameter steel penstocks	D8420	2,500,000	LBS	$0.90	$2,250,000
		Install new 15-foot diameter penstocks	D8110	1,250	LF	$3,000.00	$3,750,000
		in excavated 17-foot diameter tunnel					
		Install@ $1.50/lb &2000lb/ft					
		Place concrete in void between 17-foot diameter	D8110	2,300	CY	$250.00	$575,000
		tunnel and 15-foot diameter penstock					
		Furnish cement for penstock concreting (6 sacks/CY)	D8110	650	TONS	$110.00	$71,500
		FRP 25 add'l penstock foundations: (EQ Supports)					
		Reinforced Concrete	D8120	2,000	CY	$350.00	$700,000
		Reinforcement (100LBS/CY)	D8120	200,000	LBS	$0.60	$120,000
		Cement (6sacks/CY)	D8120	565	TONS	$110.00	$62,150
		SHEET C SUBTOTAL					$8,880,650

QUANTITIES		PRICES	
BY Anderson, Frisz	**CHECKED**	**BY**	**CHECKED** Craig A. Lush
DATE PREPARED 2-2-98	**APPROVED**	**DATE** 02/12/98	**PRICE LEVEL**

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF ____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1180

POWER OUTLETS:
NEW PENSTOCK INTAKES
ON LEFT ABUTMENT (sht 1 of 2)

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\WKSHTS\SHSTA\SHAS1180.WK4 E

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Excavate 10'x1'x 1.5" d. horiz . keys at 5' ctrs.					
		vertically into existing concrete face:					
		in dry btwn El. 1010 and 1080	D8110	140	EA	$10.00	$1,400
		in wet btwn El. 860 and 1010	D8110	300	EA	$50.00	$15,000
		Excavate 2 -foot deep by 3-foot wide slots into	D8110	900	LF	$200.00	$180,000
		existing concrete for gate frames/guides					
		between El. 865 and 925					
		Excavate 2 -foot deep by 5-foot wide key into	D8110	250	LF	$75.00	$18,750
		existing concrete for base slab at El. 860					
		Drill holes for anchor bars and grout bars in place:					
		in dry btwn El. 1010 and 1080	D8110	4,600	LF	$25.00	$115,000
		in wet btwn El. 860 and 1010	D8110	11,400	LF	$25.00	$285,000
		db					
		Concrete for new intake structures above El. 1010.0	D8110	13,250	CY	$350.00	$4,637,500
		Concrete for new intake structures below El. 1010.0	D8110	7,500	CY	$350.00	$2,625,000
		Blockout concrete for new guides and frames	D8110	195	CY	$300.00	$58,500
		between El. 865 and 925					
		Furnish and place rebar for new intakes (110lbs/CY)	D8110	2,283,000	LBS	$0.55	$1,255,650
		Furnish cement for new intakes (6 sacks/CY)	D8110	5,900	TONS	$110.00	$649,000
		Furnish and install structural steel for new intake	D8120	2,500,000	LBS	$2.00	$5,000,000
		structures between El. 1010 and 820					
		Furnish and install steel bridge plank - 9x3 -	D8120	41,600	SF	$23.00	$956,800
		3 gage - 15.3 lb/sf - btwn El. 1010 and 820					
		$1.50/LB					
		SHEET E SUBTOTAL					$15,797,600 √

QUANTITIES		PRICES	
BY LaFond	CHECKED	BY	CHECKED Craig a. Lund
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE:	PROJECT:
12-Feb-98 **SHASTA DAM ENLARGEMENT** ***EL. 1180*** **POWER OUTLETS:** **NEW PENSTOCK INTAKES** **ON LEFT ABUTMENT (sht 2 of 2)**	CENTRAL VALLEY PROJECT **DIVISION:** SHASTA **FILE:** C:\WKSHTS\SHSTA\SHAS1180.WK4 F

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Install dam connections for steel intake structure	D8120	80	EA	$25,000.00	$2,000,000
		(10 DCs/ Els. 1005, 980, 955, 930, 905, 880, 855, 820)					
		(Assume six 2"dia. anchors and 5,000# steel/ DC)					
		F&I miscellaneous metalwork at El. 1180	D8120	60,000	LBS	$5.00	$300,000
		F&I 5 Wheel-mounted gates (H=320', 20'x31')	D8420	1,647,000	LBS	$2.50	$4,117,500
		ref: Minidoka & Waddell					
		F&I 5 sets of frames and guides for whl.-mtd gates	D8420	1,307,000	LBS	$3.50	$4,574,500
		F&I 5 hoists for wheel-mounted gates	D8420	982,000	LBS	$7.00	$6,874,000
		F&I 5 control systems for wheel-mounted gates	D8420	15,000	LBS	$15.00	$225,000
		F&I 5 sets cast steel stoplog guides and seats	D8410	680,000	LBS	$2.50	$1,700,000
		Furnish 1 set of new stoplogs (El. 855 - El. 1175)	D8410	1,820,000	LBS	$2.00	$3,640,000
		Furnish 1 stoplog lifting frame	D8410	5,000	LBS	$2.00	$10,000
		F&I steel trashracks at following elevations:					
		El. 1175 - 1040 (5 tot.)	D8410	1,013,000	LBS	$2.50	$2,532,500
		El. 930 - 830 (5 tot.)	D8410	675,000	LBS	$2.50	$1,687,500
		F&I hoist-operated multi-level steel gates:					
		Upper Gate (45' x 100') (5 tot.)	D8410	1,225,000	LBS	$4.00	$4,900,000
		Lower Gate (45' x 100') (5 tot.)	D8410	1,225,000	LBS	$4.00	$4,900,000
		F&I steel guides for muti-level gates and trashracks	D8410	237,000	LBS	$2.20	$521,400
		F&I 10 multi-level gate hoists - 350,000 lbs. cap.	D8410	1,000,000	LBS	$7.00	$7,000,000
		F&I temperature monitoring equipment	D8410	1	LS	$100,000.00	$100,000
	?	F&I electrical equipment for multi-level intake	D8430	1	LS	$150,000.00	$150,000
		SHEET F SUBTOTAL					$45,232,400

QUANTITIES		PRICES	
BY LaFond, Arrington, Christensen, Ritt	**CHECKED**	**BY**	**CHECKED** Craig A. Gruel
DATE PREPARED 2-2-98	**APPROVED**	**DATE** 02/12/98	**PRICE LEVEL**

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1180

POWER OUTLETS:
NEW PENSTOCKS ON LEFT ABUTMENT

PROJECT: CENTRAL VALLEY PROJECT

DIVISION: SHASTA

FILE: C:\WKSHTS\SHSTA\SHAS1180.WK4 G

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Excavate five 22-foot diameter tunnels through dam	D8110	20,000	CY	$150.00	$3,000,000
		for new 20-foot diameter penstocks (inclined)					
		(Intake El. 880, Reservoir El. 1010)					
		Excavation for penstocks, anchors, and foundations	D8120	16,000	CY	$15.00	$240,000
		Furnish five new 20-foot dia. steel penstocks	D8420	18,600,000	LBS	$0.90	$16,740,000
		total length = 1425+3700=	5125	FT			
		Install new 20-foot diameter penstocks	D8110	1,425	LF	$5,400.00	$7,695,000
		in excavated 22-foot diameter tunnel (285' ea.)					
		install @$1.50/lb @ 3650#/ft	3629	#/FT			
		Place concrete in void between 22-foot diameter	D8110	3,500	CY	$500.00	$1,750,000
		tunnel and 20-foot diameter penstock					
		Furnish cement for penstock concreting (6 sacks/CY)	D8110	990	TONS	$110.00	$108,900
		FRP new penstock foundations and anchors:					
		Reinforced Concrete	D8120	15,000	CY	$350.00	$5,250,000
		Reinforcement (100LBS/CY)	D8120	150,000	LBS	$0.60	$90,000
		Cement (6sacks/CY)	D8120	4,300	TONS	$110.00	$473,000
		Install exposed portions of new 20-foot diameter	D8420	3,700	LF	$3,600.00	$13,320,000
		penstocks (740' ea.)					
		install @$1.00/lb					
		SHEET G SUBTOTAL					$48,666,900 √

QUANTITIES		PRICES	
BY Anderson, Frisz	CHECKED	BY	CHECKED Craig A. Gush
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1180

POWER OUTLETS:
NEW POWERPLANT ON LEFT ABUTMENT (Sht 1 of 3)

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\WKSHTS\SHSTA\SHAS1180.WK4 H

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Excavation for new powerplant (rock)	D8120	1,540,000	CY	$15.00	$23,100,000
		Dewatering for new powerplant	D8120	1	LS	$1,200,000.00	$1,200,000
		(Assume 500 gpm for 1 year)					
		install + operate					
		Concrete in Substructure	D8120	36,800	CY	$350.00	$12,880,000
		Concrete in Intermediate Structure	D8120	28,700	CY	$400.00	$11,480,000
		Concrete in Superstructure	D8120	9,200	CY	$450.00	$4,140,000
		Concrete in Second Stage	D8120	24,000	CY	$350.00	$8,400,000
		Furnish and handle cement for new powerplant	D8120	28,000	TONS	$110.00	$3,080,000
		(6 sacks/CY)					
		Furnish and place reinforcement in new powerplant	D8120	10,850,000	LBS	$0.50	$5,425,000
		Structural Steel in Superstructure	D8120	750,000	LBS	$1.80	$1,350,000
		(crane beams/ rails, roof)					
		Miscellaneous metalwork for new powerplant	D8120	200,000	LBS	$4.50	$900,000
		(ladders, guardrails, catwalks, stairs, hatches)					
		Heating and ventilating for new powerplant	D8410	1	LS	$200,000.00	$200,000
		note[?]: 20 kW cap.					
		priced @ $5.00/sf for LB area only					
		Sanitary systems for new powerplant	D8410	1	LS	$120,000.00	$120,000
		priced @ $3.00/sf for LB area only					
		Lighting system for new powerplant	D8430	1	LS	$564,600.00	$564,600
		HB LIGHTING [MH or MV]		56,400	FT2	$6.50	
		LB LIGHTING [FLUR]		39,600	FT2	$5.00	
		Electrical system for new powerplant	D8430	1	LS	$192,000.00	$192,000
		COST/FT2	$2.00	excluding lights			
		SHEET H SUBTOTAL					$73,031,600 ✓

QUANTITIES		PRICES	
BY Anderson, LaFond	CHECKED	BY	CHECKED Craig A. Gurl
DATE PREPARED 2-2-98	APPROVED	DATE 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF _____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1180

POWER OUTLETS:
NEW POWERPLANT ON LEFT ABUTMENT (Sht 2 of 3)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION: SHASTA

FILE: C:\WKSHTS\SHSTA\SHAS1180.WK4 I

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		F&I five new turbines (260MW, 163.64 rpm,	D8420	5,950,000	LBS	$12.00	$71,400,000
		575' design head, 1,340,000 lbs/ea.)					
		G. Coulee new units					
		F&I five governors - 850,000 ft-lbs - 65,000 ea.	D8420	305,000	LBS	$10.00	$3,050,000
		F&I 2 Generator CO2 system - 15,500lbs/ea	D8420	27,400	LBS	$8.00	$219,200
		F&I Unit cooling water piping system, governor and	D8420	225,000	LBS	$8.00	$1,800,000
		lube oil piping system (5 at 45,000 lbs/ea)					
		F&I plant water piping and fire protection system	D8420	105,000	LBS	$6.00	$630,000
		(5 at 7,000 lbs/ea)					
		F&I transformer oil fire protection piping system	D8420	225,000	LBS	$6.00	$1,350,000
		(5 at 45,000 lbs/ea)					
		F&I compressed air piping system (5 at 7,000 lbs/ea)	D8420	35,000	LBS	$6.00	$210,000
		F&I exposed piping system (5 at 39,000 lbs/ea)	D8420	195,000	LBS	$6.00	$1,170,000
		F&I unwatering piping system (5 at 39,000 lbs/ea)	D8420	195,000	LBS	$4.00	$780,000
		F&I drainage piping system (5 at 36,000 lbs/ea)	D8420	180,000	LBS	$4.00	$720,000
		F&I two 500T overhead travelling cranes,	D8410	2	EA	$1,500,000.00	$3,000,000
		span=70 ft, (600,000 lbs/ea)					
		priced @ 2.50/lb - ref: Richardson					
		Furnishing and installing 15 kV SF6 power circuit	D8430	5	EA	$155,000.00	$775,000
		breaker, 12,5000 amp continous current, 105 kA					
		rms symm interupting (8 cycle) rating					
		Means: gas breakers					
		Furnishing and installing 260 MW, 0.95 PF	D8430	5	EA	$8,800,000.00	$44,000,000
		163.64 rpm, 13,800 volt, vertical synchronous					
		generator with static excitation system					
		SHEET I SUBTOTAL					$129,104,200 ✓

QUANTITIES		PRICES	
BY: Zelenka, Ritt, Rossi	CHECKED	BY	CHECKED: Craig A. Gruel
DATE PREPARED: 2-2-98	APPROVED	DATE: 02/12/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET____ OF_____

FEATURE: 12-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1180

POWER OUTLETS:
NEW POWERPLANT ON LEFT ABUTMENT (Sht 3 of 3)

PROJECT: CENTRAL VALLEY PROJECT

DIVISION: SHASTA

FILE: C:\WKSHTS\SHSTA\SHAS1180.WK4 J

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Furnishing and installing 3 ph, 15 kV, 12,500 amp isolated phase bus	D8430	500	LF	$1,750.00	$875,000
		Furnishing and installing a 480-volt, 1200 amp double-ended station service switchgear assembly with 5 vertical sections	D8430	1	EA	$175,000.00	$175,000
		Furnishing and installing 600-volt motor control centers rated 800 amps with 5 vertical sections	D8430	5	EA	$60,000.00	$300,000
		Furnishing and installing duplex control switchboard with 12 sections	D8430	1	EA	$220,000.00	$220,000
		Furnishing and installing station service transformer rated 1500 kVA , 13.8 kV-277\480 V	D8430	2	EA	$35,000.00	$70,000
		Furnishing and installing 1-phase, outdoor oil-filled generator step up transformer rated 91 kVA, FOA, 230 kV Gnd Y/ 13.8 kV Delta, 825\110 kV BIL	D8440	16	EA	$8,000.00	$128,000
		SHEET J SUBTOTAL					$1,768,000
		SHEET A					$13,295,450
		SHEET B					$15,513,840
		SHEET C					$8,880,650 ✓
		SHEET D					none
		SHEET E					$15,797,600
		SHEET F					$45,232,400 ✓
		SHEET G					$48,666,900
		SHEET H					$73,031,600
		SHEET I					$129,104,200 ✓
		SHEET J					$1,768,000
		TOTAL					$351,290,640 ✓

QUANTITIES		PRICES	09:16 AM
BY Rossi	**CHECKED**	**BY** L. PEDDE	**CHECKED** Craig A. [illegible]
DATE PREPARED 2-2-98	**APPROVED**	**DATE** 02/12/98	**PRICE LEVEL** APP.

CODE: D 8170

ESTIMATE WORKSHEET

SHEET 2 OF 2

FEATURE: **SHASTA DAM ENLARGEMENT** *EL 1180:* **COST SUMMARY**	PROJECT:
	DIVISION / REGION: MP
	CONTRACT/SPEC:
WOID: SHDES	FILE: C:\WKSHTS\SHSTA\SUM1180.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION 09:49 AM	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		POWERPLANT STRUCTURES					
		FILE: SHAS1180.WK4					
		LINKED FILE DATA					
		FILE SUBTOTAL					$351,290,640.00 ✓
		MOBILIZATION	+/-	5.0%			$17,500,000.00 ✓
		SUBTOTAL					$368,790,640.00 ✓
		UNLISTED	+/-	15.0%			$51,209,360.00 ✓
		ESTIMATED CONTRACT COST					$420,000,000.00 ✓
		CONTINGENCIES	+/-	25.0%			$110,000,000.00 ✓
		EST. FIELD COST					$530,000,000.00 ✓

QUANTITIES		PRICES	
BY	APPROVED	BY L Pedde L. PEDDE	CHECKED Craig A. Gust
DATE PREPARED	DATE	DATE 12-Feb-98	PRICE LEVEL

CODE:D-3521

ESTIMATE WORKSHEET

FEATURE: 05-Feb-98	PROJECT: CENTRAL VALLEY	
SHASTA POWER PLANT 230/525 KV SWITCHYARD *EL. 1180*	DIVISION: CIVIL ENGINEERING	UNIT: D-8120
	FILE: A:\SHDES118.WK4	

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		NEW SWITCHYARD:					
		Furnishing and erecting takeoff structures		92,000	lb	$2.50	$230,000.00
		Furnishing and erecting switchyard supports		457,000	lb	$2.10	$959,700.00
		Excavation for switchyard foundations		195,000	cu. yd	$4.50	$877,500.00
		Placing and compacting backfill		192,000	cu. yd	$7.50	$1,440,000.00
		Furnishing and placing 6" gravel surfacing		36,000	sq yd	$6.50	$234,000.00
		Furnishing and placing gravel for gravelfills		1,200	cu. yd	$30.00	$36,000.00
		Furnishing and applying soil-applied herbicide		36,000	sq. yd	$0.80	$28,800.00
		Furnishing and placing concrete in switchyard foundations		2,900	cu. yd	$350.00	$1,015,000.00
		Furnishing and handling cementitous materials		818	tons	$115.00	$94,070.00
		Furnishing and placing reinforcing bars in switchyard foundations		500,000	lb	$0.70	$350,000.00

QUANTITIES		PRICES	
BY Gerald Sherard	CHECKED	BY L.PEDDE	CHECKED Craig A. Gruek
DATE PREPARED January 16,1998	APPROVED	DATE 05-Feb-98	PRICE LEVEL APPR

CODE:D-3521

ESTIMATE WORKSHEET

FEATURE: 05-Feb-98

SHASTA POWER PLANT
230/525 KV SWITCHYARD
EL. 1180 APPRAISAL ESTIMATE

PROJECT: CENTRAL VALLEY

DIVISION: CIVIL ENGINEERING

UNIT: D-8120

FILE: A:\SHDES118.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Furnishing and erecting 7-foot-high chain link fence		2,400	ft	$24.00	$57,600.00
		Furnishing and installing oil containment system		1	LS	$50,000.00	$50,000.00
		DEMOLITON OF OLD SWITCHYARD:					
		Remove lattice steel structures		1,000,000	lb	$0.25	$250,000.00
		Remove concrete foundations		6,000	cu. yd	$200.00	$1,200,000.00
		(Excavation and embankment covered under new power plant construction on old switchyard site)					
		SUBTOTAL					$6,822,670.00 ✓

QUANTITIES		PRICES	
BY: Gerald Sherard	CHECKED:	BY: L.PEDDE	CHECKED: Craig A. Gush
DATE PREPARED: January 16,1998	APPROVED:	DATE: 05-Feb-98	PRICE LEVEL: APPR

CODE: D 8170

ESTIMATE WORKSHEET

SHEET 1 OF

FEATURE: Elev 1180 - Alt B
230/525 kV Switchyards
Existing PP & New PP

WOID: SHDES

PROJECT: SHASTA DAM ENL.
DIVISION / REGION: MP
CONTRACT/SPEC:
FILE: A:\EST_2SH.WK4

12:00 PM

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	3Ø Gang Oper 550 kV Disc Sw, 3,000 A Cont, 64 kA Momentary	D8440	4	ea	$75,000.00	$300,000.00
	2	3Ø Gang Oper 242 kV Disc Sw, 3,000 A Cont,100 kA Momentary	D8440	51	ea	$30,000.00	$1,530,000.00
	3	550 kV Circuit Breaker, 3,000 A Cont, 40 kA Int Rat, 2 Cyc Int Time, 1,800 kV BIL	D8440	3	ea	$750,000.00	$2,250,000.00
	4	242 kV Circuit Breaker, 3,000 A Cont, 63 kA Int Rat, 3 Cyc Int Time, 900 kv BIL	D8440	18	ea	$200,000.00	$3,600,000.00
	5	335 kV MCOV, Station Class Surge Arrester	D8440	3	ea	$8,500.00	$25,500.00
	6	156 kv MCOV, Station Class Surge Arrester	D8440	33	ea	$6,600.00	$217,800.00
	7	1Ø -333,000/433,333 kVA FOA 525 GrdY / 230 GrdY / 13.8 kV, 1425 / 750 / 110 kV BIL, 35% Tert Rating Power Transformer	D8440	4	ea	$6,000,000.00	$24,000,000.00
	8	4/0 Copper Ground Cable for 230 kV Swyd	D8440	20,000	ft	$7.50	$150,000.00
	9	4/0 Copper Ground Cable for 500 kV Swyd	D8440	6,000	ft	$7.50	$45,000.00
	10	Copper Ground Rods for 230 kV & 525 kV Swyds	D8440	400	ea	$100.00	$40,000.00
	11	6" Rigid Alum Bus (230 kV Swyd)	D8440	5,000	feet	$100.00	$500,000.00
	12	3" Rigid Alum Bus (525 kV Swyd)	D8440	1,500	feet	$40.00	$60,000.00
	13	Misc Alum Bus Conn (230 kV & 525 kV Swyd)	D8440	1	LS	$50,000.00	$50,000.00
	14	Misc Conduit (230 kV & 525 kV Swyd)	D8440	1	LS	$50,000.00	$50,000.00
	15	Removal of 40 ea 230 kv air switches, 9 ea 230 kV circuit breakers, and misc CTs, PTs, surge arresters etc. from existing switchyard.	D8440	1	LS	$15,000.00	$15,000.00
		SHEET SUBTOTAL					$32,833,300.00 √

QUANTITIES		PRICES	
BY	APPROVED	BY L. PEDDE	CHECKED Craig A. Lusk
DATE PREPARED	DATE	DATE 09-Feb-98	PRICE LEVEL APPRAISAL

CODE: D 8170

ESTIMATE WORKSHEET

FEATURE:
SHASTA DAM ENLARGEMENT
EL 1180: **COST SUMMARY**

PROJECT:
DIVISION / REGION: MP
CONTRACT/SPEC:
FILE: C:\WKSHTS\SHSTA\SUM1180.WK4

WOID: SHDES

09:49 AM

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		SWITCHYARD - CIVIL					
		FILE: SHDES118.WK4					
		LINKED FILE DATA					
		FILE SUBTOTAL					$6,822,670.00 ✓
		MOBILIZATION	+/-	5.0%			$350,000.00 ✓
		SUBTOTAL					$7,172,670.00 ✓
		UNLISTED	+/-	15.0%			$1,027,330.00 ✓
		ESTIMATED CONTRACT COST					$8,200,000.00 ✓
		CONTINGENCIES	+/-	25.0%			$2,100,000.00 ✓
		EST. FIELD COST					$10,300,000.00 ✓
		SWITCHYARD - ELECTRICAL					
		FILE: EST_2SH.WK4					
		LINKED FILE DATA					
		FILE SUBTOTAL					$32,833,300.00 ✓
		MOBILIZATION	+/-	5.0%			$1,650,000.00 ✓
		SUBTOTAL					$34,483,300.00 ✓
		UNLISTED	+/-	15.0%			$5,516,700.00 ✓
		ESTIMATED CONTRACT COST					$40,000,000.00 ✓
		CONTINGENCIES	+/-	25.0%			$10,000,000.00 ✓
		EST. FIELD COST					$50,000,000.00 ✓

QUANTITIES		PRICES	
BY	APPROVED	BY L Pedde L. PEDDE	CHECKED Craig A. Gusk
DATE PREPARED	DATE	DATE 12-Feb-98	PRICE LEVEL

CODE:CE 3323

ESTIMATE WORKSHEET

FEATURE:

Shasta Lake Enlargement
Elevation 1180 feet

PROJECT: Central Valley

DIVISION:

FILE:

CONTRACT COST	QTY	CONTRACT COST JAN. 82	FIELD COST (CONTINGENCIES +/- 25 %) JAN. 82	USBR INDEX JAN. 82	USBR INDEX OCT. 97	AMOUNT
Resort Location and Land Rights	LS	$30,000,000	$38,000,000	144	222	$59,000,000
Public Recreation Relocation	LS	$108,000,000	$135,000,000	144	222	$210,000,000
Reservoir Clearing (1)	16000	$1,200	$24,000,000			$24,000,000
Recreation Facilities	LS	$24,500,000	$31,000,000	144	222	$48,000,000
Sacramento River Seepage Mitigation	LS	$22,200,000	$28,000,000	144	222	$43,000,000
Subtotal 1						$384,000,000

(1) Computed for 1998 costs

QUANTITIES		PRICES	
BY T. Hepler	CHECKED	BY T. Bergt R. Baumgarten	CHECKED Craig A. Gush
DATE PREPARED 20-Feb-98	APPROVED	DATE 20-Feb-98	PRICE LEVEL

ESTIMATE WORKSHEET

FEATURE:
Shasta Lake Enlargement
Elevation 1180 feet

PROJECT: Central Valley

DIVISION:

FILE:

CONTRACT COST	QTY	CONTRACT COST APR. 84	FIELD COST (CONTINGENCIES +/- 25 %) APR. 84	USBR INDEX APR. 84	USBR INDEX OCT. 97	AMOUNT
Southern Pacific Railroad Relocation (APR 84)						
Earthwork	LS	$70,300,000	$88,000,000	154	224	$130,000,000
Railroad	LS	$29,400,000	$37,000,000	154	224	$54,000,000
Bridges	LS	$40,900,000	$51,000,000	155	232	$76,000,000
Tunnels	LS	$51,500,000	$64,000,000	161	234	$93,000,000
I-5 Relocation (APR 84)						
Earthwork	LS	$44,100,000	$55,000,000	154	224	$80,000,000
Roadway	LS	$17,400,000	$22,000,000	154	224	$32,000,000
Bridges	LS	$33,400,000	$42,000,000	155	232	$63,000,000
Interchanges	LS	$2,900,000	$3,600,000	154	224	$5,200,000
Land Acquisition	LS	$550,000	$690,000	155	222	$990,000
Subtotal 2						$534,190,000
Total (Subtotal 1 + Subtotal 2)						$918,190,000

QUANTITIES		PRICES	
BY T. Hepler	CHECKED	BY R. Baumgarten	CHECKED Craig A. Gush
DATE PREPARED 20-Feb-98	APPROVED	DATE 20-Feb-98	PRICE LEVEL

APPENDIX D-3 **ESTIMATE WORKSHEET**

CODE:D-8170

SHEET 1 OF 1

FEATURE:

SHASTA DAM
ENLARGEMENT - EL. 1084

Dam Enlargement and Structures

Appraisal Level Est. - Jan. 98

19-Feb-98

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\TOTL1084.WK4

REVISON: 01

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Removal of Structures for Concrete Dam Raise			ls		$7,200,000
	2	Concrete Dam and Reinforced Earth Wing Dams			ls		$15,500,000
	3	Spillway			ls		$22,000,000
	4	River Outlet Works			ls		$15,500,000
	5	Modifications to existing penstock and penstoke intake			ls		$10,500,000
				TOTAL Elev. 1084			$70,700,000

QUANTITIES		PRICES	
BY T Hepler	CHECKED	BY: R. Baumgarten, K.Copeland	CHECKED 2/19/98
DATE PREPARED	APPROVED	DATE 02/19/98	PRICE LEVEL Appraisal 98

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 13-Feb-98

SHASTA DAM
ENLARGEMENT - EL. 1084

REMOVAL OF STRUCTURES
FOR CONCRETE DAM RAISE

PROJECT:
CENTRAL VALLEY PROJECT

DIVISION:

FILE:
C:\123R4D\EST\SHASTA~1\SHST843.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$250,000
	2	Removal of gantry crane and rails from dam crest	D8410	841,000	lbs	$0.30	$252,30
	3	Removal of spillway drum gates and frames	D8420	3,255,000	lbs	$0.60	$1,953,00
	4	Removal of drum gate control equipment	D8420	90,000	lbs	$0.75	$67,500
	5	Removal of structural steel in spillway bridge		976,000	lbs	$0.30	$292,800
	6	Removal of concrete in spillway bridge and piers	D8130	2,800	yd3	$250.00	$700,00
	7	Removal of concrete in sidewalks and parapet walls	D8130	1,100	yd3	$500.00	$550,000
	8	Removal of concrete in spillway crest	D8130	3,530	yd3	$300.00	$1,059,000
	9	Removal of misc. concrete on both abutments	D8130	820	yd3	$100.00	$82,00
		Subtotal					**$5,206,60**
		Unlisted items @ 10 percent					**$493,400**
		Contract cost					**$5,700,00**
		Contingencies @ 25 percent					**$1,500,00**
		Field cost					**$7,200,000**

QUANTITIES		PRICES	
BY R. Benik	**CHECKED** T. Hepler	**BY** R. Baumgarten	**CHECKED** Craig A. Gush
DATE PREPARED 02/04/98	**APPROVED**	**DATE** 02/13/98	**PRICE LEVEL**

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 13-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1084

CONCRETE DAM AND REINFORCED EARTH WING DAMS

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHST843.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$1,000,000
	2	Excavation on abutments, common	D8130	1,200	yd3	$8.00	$9,600
	3	Pervious backfill in reinforced-earth wing dams	D8130	4,100	yd3	$65.00	$266,500
	4	Mass concrete in dam raise	D8130	20,000	yd3	$265.00	$5,300,000
	5	Concrete in sidewalks and parapet walls on dam	D8130	1,100	yd3	$450.00	$495,000
	6	Concrete on crest of reinforced-earth wing dams	D8130	1,100	yd3	$250.00	$275,000
	7	Leveling concrete for precast concrete panels	D8130	20	yd3	$500.00	$10,000
	8	Furnishing and handling cement	D8130	3,100	tons	$110.00	$341,000
	9	Furnishing and handling pozzolan	D8130	1,200	tons	$60.00	$72,000
	10	Furnishing and installing precast concrete panels for reinforced-earth wing dams	D8130	1,200	yd2	$320.00	$384,000
	11	Furnishing and installing 12-inch PVC waterstop	D8130	290	lft	$15.00	$4,350
	12	Furnishing and placing reinforcing bars	D8130	330,000	lbs	$0.60	$198,000
	13	Extending 5-inch formed drains in dam to new crest	D8130	2,100	lft	$25.00	$52,500
	14	Gantry crane and rails, 125 tons, right side	D8410	605,000	lbs	$3.50	$2,117,500
	15	Lighting system for dam crest (56 kw)	D8430	110,000	sf	$6.50	$715,000
		Subtotal					**$11,240,450**
		Unlisted items @ 10 percent					**$1,259,550**
		Contract cost					**$12,500,000**
		Contingencies @ 25 percent					**$3,000,000**
		Field cost					**$15,500,000**

QUANTITIES		PRICES	
BY J. Ellingson	CHECKED T. Hepler	BY R. Baumgarten	CHECKED Craig A. Gush
DATE PREPARED 02/04/98	APPROVED	DATE 02/13/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: SHASTA DAM ENLARGEMENT - EL. 1084 SPILLWAY	13-Feb-98	PROJECT: CENTRAL VALLEY PROJECT DIVISION: FILE: C:\123R4D\EST\SHASTA~1\SHST843.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$770,000
	2	Concrete in spillway crest	D8130	20,000	yd3	$250.00	$5,000,000
	3	Deleted					
	4	Concrete in spillway bridge piers	D8130	5,700	yd3	$260.00	$1,482,000
	5	Concrete in operating and roadway bridges	D8130	1,400	yd3	$600.00	$840,000
	6	Furnishing and handling cement	D8130	6,200	tons	$110.00	$682,000
	7	Furnishing and handling pozzolan	D8130	1,500	tons	$60.00	$90,000
	8	Furnishing and placing reinforcing bars	D8130	20,000	lbs	$0.65	$13,000
	9	Six spillway radial gates, 55 by 27.5 feet	D8420	1,155,000	lbs	$3.00	$3,465,000
	10	Embedded metalwork for six radial gates	D8420	284,000	lbs	$3.50	$994,000
	11	Six radial gate hoists, 164,000 lb capacity each	D8410	295,200	lbs	$7.00	$2,066,400
	12	Gantry crane and rails, 60 ton capacity	D8410	246,000	lbs	$3.50	$861,000
		Subtotal					**$16,263,400**
		Unlisted items @ 10 percent					**$1,736,600**
		Contract cost					**$18,000,000**
		Contingencies @ 25 percent					**$4,000,000**
		Field cost					**$22,000,000**

QUANTITIES		PRICES	
BY R. Benik	CHECKED T. Hepler	BY L. Byrt	CHECKED Craig A. Grush
DATE PREPARED 02/12/98	APPROVED	DATE 02/13/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 13-Feb-98

SHASTA DAM ENLARGEMENT - EL. 1084

RIVER OUTLETS

PROJECT: CENTRAL VALLEY PROJECT

DIVISION:

FILE: C:\123R4D\EST\SHASTA~1\SHST84A.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Mobilization and preparatory work	D8130	Lump sum	ls		$540,000
	2	Removal of four 102-inch tube valves	D8420	1,032,000	lbs	$0.40	$412,800
	3	Removal of valve operating systems	D8420	12,000	lbs	$0.85	$10,200
	4	Excavation of concrete for four new gate chambers	D8130	510	yd3	$600.00	$306,000
	5	Concrete in four new gate chambers	D8130	450	yd3	$450.00	$202,500
	6	Furnishing and handling cement	D8130	100	tons	$120.00	$12,000
	7	Furnishing and handling pozzolan	D8130	26	tons	$80.00	$2,080
	8	Furnishing and placing reinforcing bars	D8130	68,000	lbs	$0.65	$44,200
	9	Eight 102-inch ring-follower gates, 340-ft head	D8130	1,296,000	lbs	$7.00	$9,072,000
	10	Control systems for eight gates	D8420	24,000	lbs	$20.00	$480,000
	11	Furnish and install 102-inch steel liners for outlets	D8420	50,000	lbs	$3.50	$175,000
	12	Furnish and install air valves and filling lines	D8420	450	lbs	$20.00	$9,000
		Subtotal					**$11,265,780**
		Unlisted items @ 10 percent					**$1,234,220**
		Contract cost					**$12,500,000**
		Contingencies @ 25 percent					**$3,000,000**
		Field cost					**$15,500,000**

QUANTITIES		PRICES	
BY J. Ellingson	CHECKED T. Hepler	BY RKC K. Copeland	CHECKED R. Baumgarten RBB 2/11/98
DATE PREPARED 02/04/98	APPROVED	DATE 02/13/98	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 19-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1084

POWER OUTLETS:
MODIFICATIONS TO EXISTING TEMPERATURE CONTROL DEVICE

PROJECT: 01:23 PM
CENTRAL VALLEY PROJECT

DIVISION:
SHASTA

FILE:
C:\123R4D\EST\SHASTA~1\SHAS1084.WK A

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		(Note: Construction WS EL. 1010.0)					
		Remove existing 17 TCD gate hoists	D8410	884,000	LBS	$0.50	$442,000
		Remove existing electrical control equipment (5 MCCs, 1 Distribution switchboard)	D8430	1	LS		$10,000
		Remove existing miscellaneous metalwork	D8120	175,000	LBS	$1.00	$175,000
		Remove existing hoist platform steel at El. 1067.5	D8120	750,000	LBS	$0.50	$375,000
		F&I new trashrack panels in the dry at El. 1067.5	D8410	477,000	LBS	$2.50	$1,192,500
		F&I new structural steel trashrack and hoist support structure in dry between El. 1067.5 and El. 1080	D8120	630,700	LBS	$2.50	$1,576,750
		Reinstall hoist platform steel at El. 1080	D8120	750,000	LBS	$1.00	$750,000
		Reinstall existing 17TCD gate hoists	D8410	884,000	LBS	$1.00	$884,000
		Reinstall existing misc. metalwork at El. 1080.0	D8120	175,000	LBS	$2.00	$350,000
		Reinstall existing electrical control equipment (5 MCCs, 1 Distribution switchboard, conduit)	D8430	1	LS		$25,000
							5,780,250
		(Note: Construction WS EL. 1010.0)					
		PENSTOCK INTAKES:					
		Remove existing misc. metalwork	D8110	8,800	LBS	$0.40	$3,520
		Remove 5 existing coaster gate operators at El. 1068.7	D8420	1	LS		$10,000
		Plug stairs to 1065 gallery w/conc.	D8110	20	CY	$600.00	$12,000

QUANTITIES		PRICES	
BY LaFond, Christensen,	CHECKED	BY R. Baumgarten	CHECKED
DATE PREPARED 2-19-98	APPROVED	DATE 02/19/98	PRICE LEVEL APPR.

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 19-Feb-98

SHASTA DAM ENLARGEMENT
EL. 1084

POWER OUTLETS:
MODIFICATIONS TO EXISTING PENSTOCK AND PENSTOCK INTAKE

PROJECT: CENTRAL VALLEY PROJECT

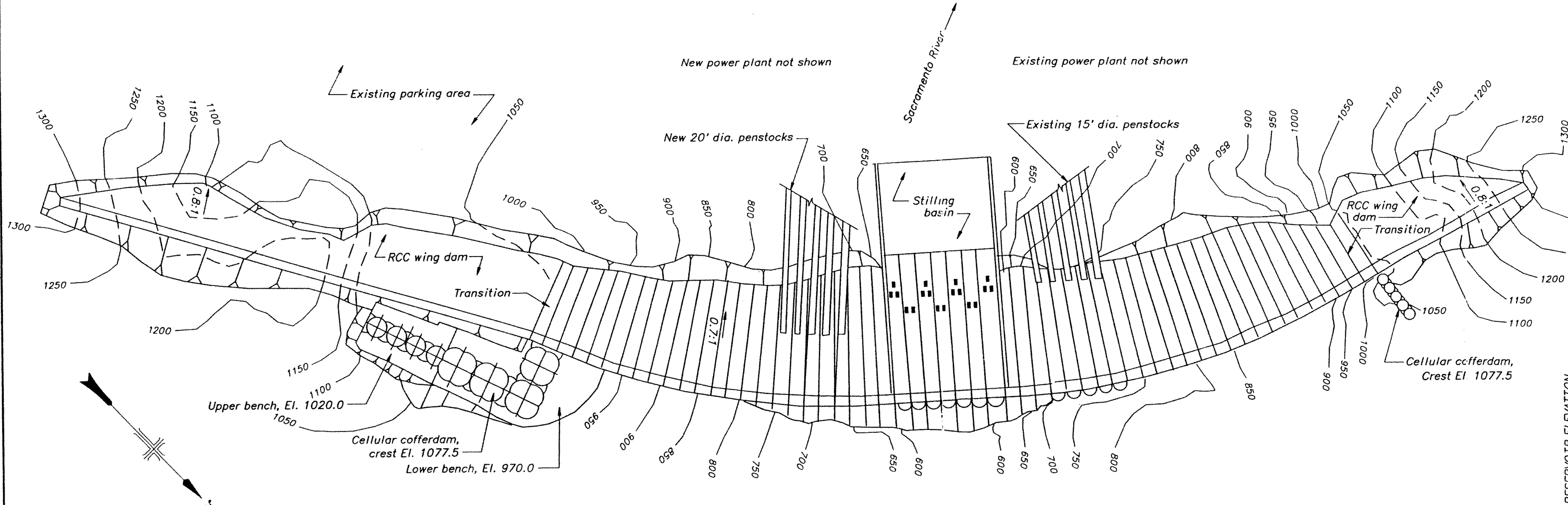
DIVISION: SHASTA

FILE: C:\123R4D\EST\SHASTA~1\SHAS1084.WK B

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Extend existing gate hoist structure from El 1077.5					
		to El. 1084.0:					
		a. Reinforced Concrete	D8120	100	CY	$350.00	$35,000
		b. Reinforcement (120LBS/CY)	D8120	12,000	LBS	$1.00	$12,000
		c. Cement (6sacks/CY)	D8120	28	TONS	$125.00	$3,500
		F&I new steel support for gate operators	D8120	25,000	LBS	$4.00	$100,000
		F&I miscellaneous metalwork (hatches, grating)	D8120	10,000	LBS	$6.00	$60,000
		Add approximately 7 feet to each coaster gate stem an	D8420	1	LS		$20,000
		reinstall 5 existing coaster gate operators at El. 1080					
		Extend existing control systems to gate operators	D8420	1	LS		$5,000
		Extend existing electrical system for gate operation	D8430	1	LS		$2,000
		F&I cast steel stoplog guides - El. 1077.5 to El. 1084	D8410	13,000	LBS	$3.50	$45,500
		PENSTOCKS:					
		FRP 25 add'l penstock foundations: (EQ Supports)					
		Reinforced Concrete	D8120	2,000	CY	$350.00	$700,000
		Reinforcement (100LBS/CY)	D8120	200,000	LBS	$0.65	$130,000
		Cement (6sacks/CY)	D8120	565	TONS	$110.00	$62,150
		Mobilization					**$350,000**
		Subtotal					**$7,330,920**
		Unlisted Items (15% +/-)					**$1,069,080**
		Contract Cost					**$8,400,000**
		Contingencies (25% +/-)					**$2,100,000**
		Field Cost					**$10,500,000**

QUANTITIES		PRICES	
BY LaFond, Anderson	CHECKED	BY R. Baumgarten	CHECKED 2/19/98
DATE PREPARED 2-19-98	APPROVED	DATE 02/19/98	PRICE LEVEL

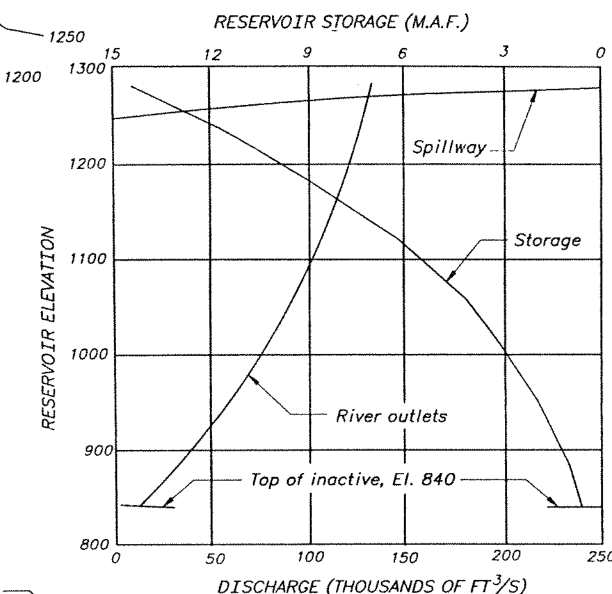
214-D-23982



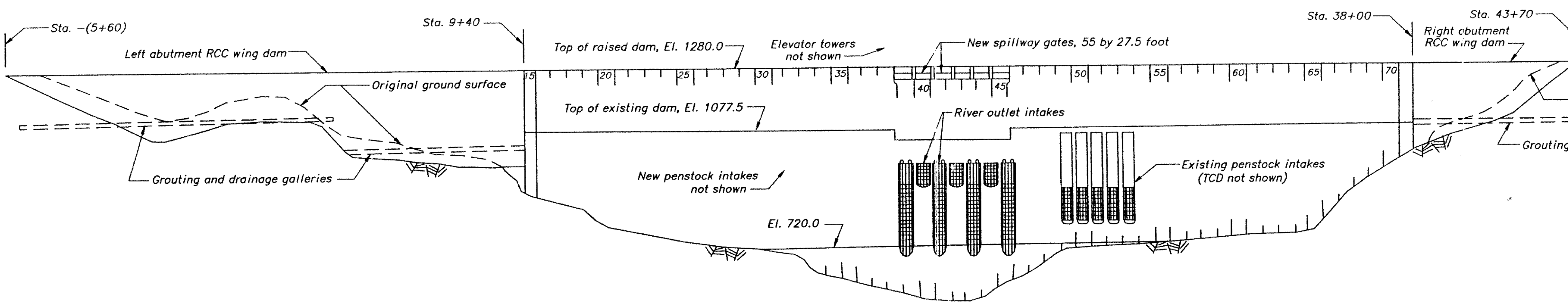
Shasta Reservoir

PLAN

200 0 200 400 600
SCALE OF FEET



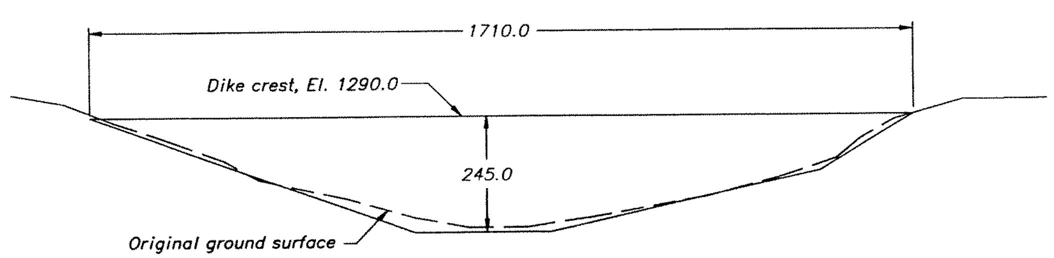
DISCHARGE – RESERVOIR STORAGE



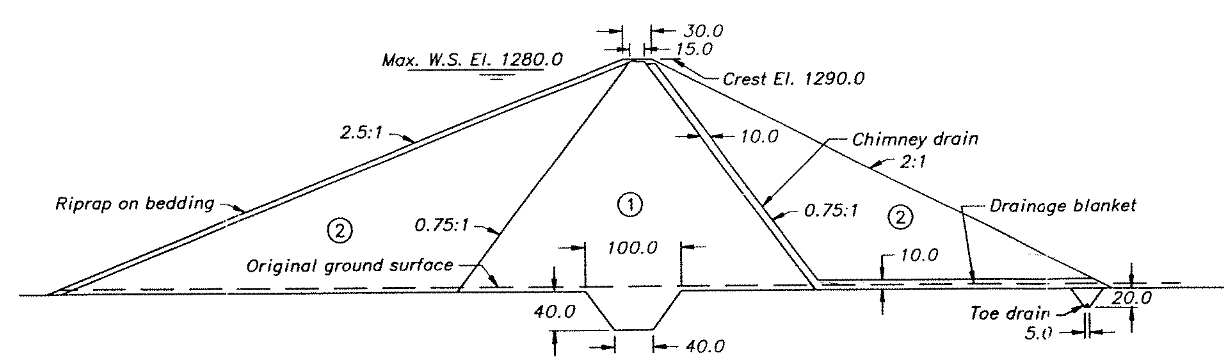
PROFILE
DEVELOPED ALONG AXIS LOOKING DOWNSTREAM

NOTES

1. Shasta Dam plan and profile based on drawing 214-D-21946.
2. Grout and drain holes not shown.



PROFILE – JONES VALLEY DIKE



SECTION – JONES VALLEY DIKE
(CENTIMUDI, CLICKAPUDI CREEK, AND BAY BRIDGE DIKES SIMILAR)

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT – CALIFORNIA

SHASTA DAM MODIFICATIONS

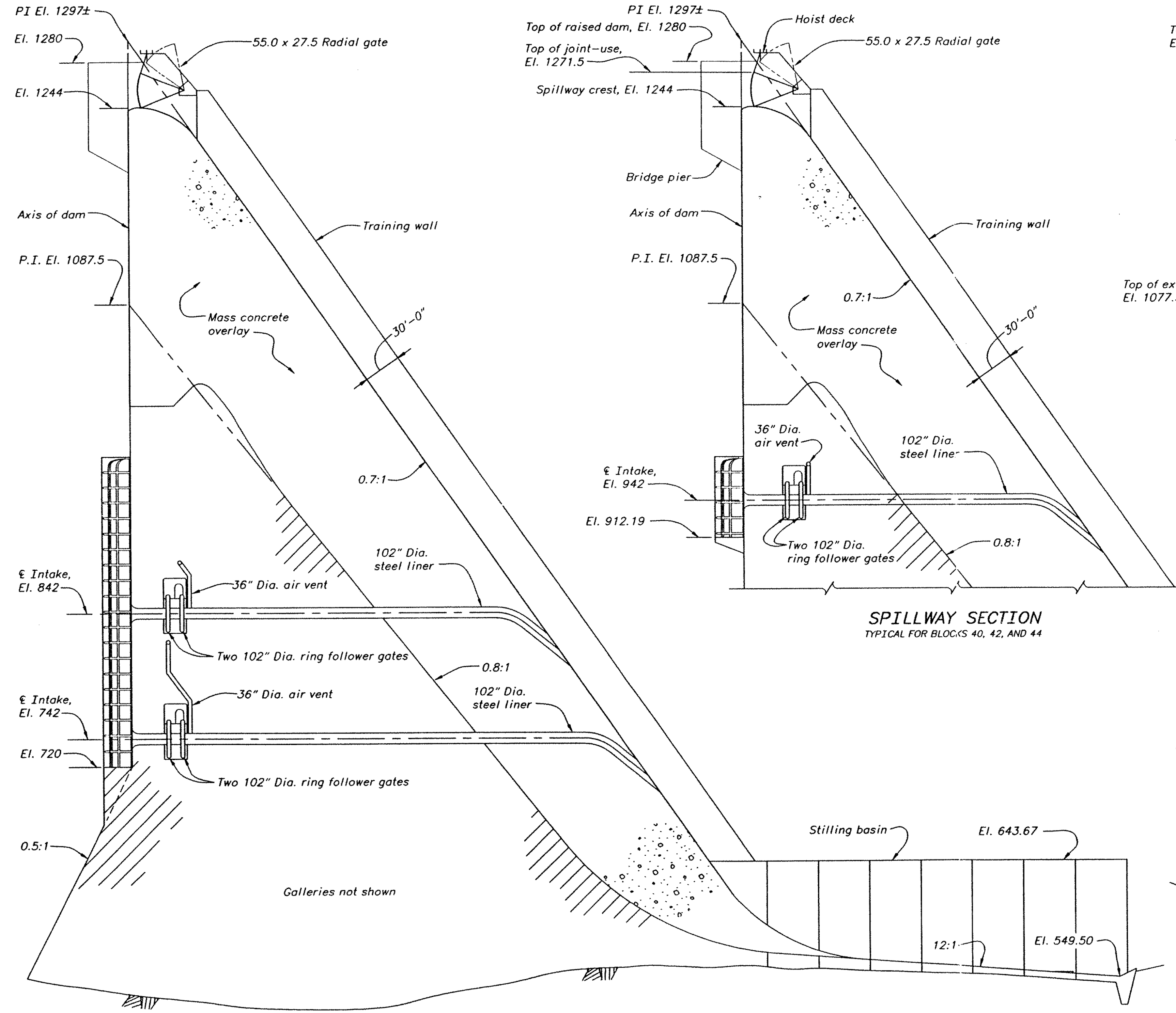
PLAN, PROFILES, AND SECTIONS – CREST EL. 1280

APPRAISAL DESIGN

DESIGNED T. HEPLER, R. TORRES TECH. APPR. T.C. Hepler
DRAWN C. STRICKLAND
CHECKED R. BENIK PEER REVIEW
WATERWAYS AND CONCRETE DAMS GROUP

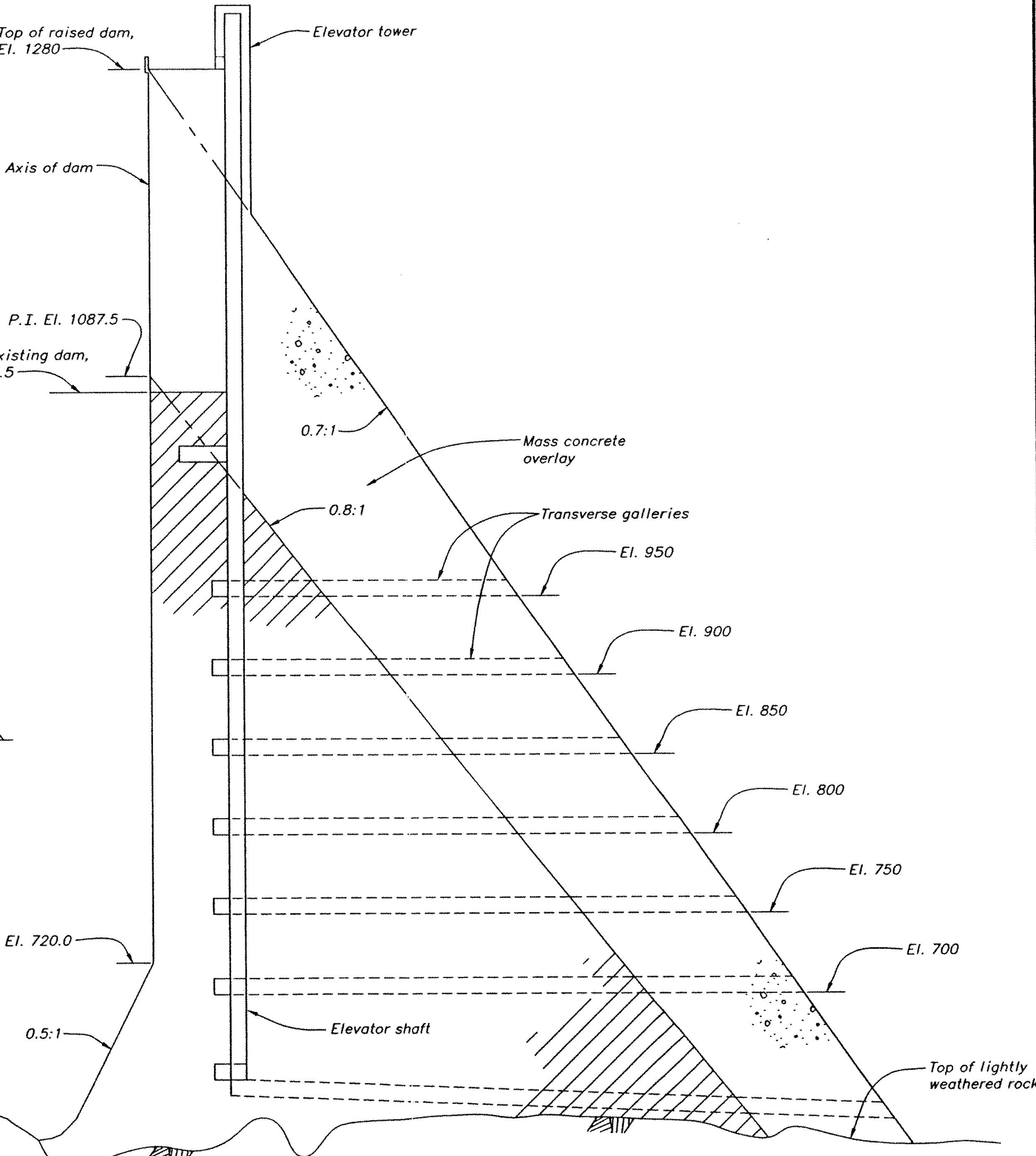
CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
AutoCAD Rel. 14.0	21423982.DWG.DWG	FEBRUARY 24, 1998 09:24
DENVER, COLORADO	FEBRUARY 17, 1998	214-D-23982

SHEET 1 OF 3



MAXIMUM SPILLWAY SECTION
TYPICAL FOR BLOCKS 39, 41, 43, AND 45

SPILLWAY SECTION
TYPICAL FOR BLOCKS 40, 42, AND 44



GRAVITY SECTION – STA. 25 + 25
BLOCK 46

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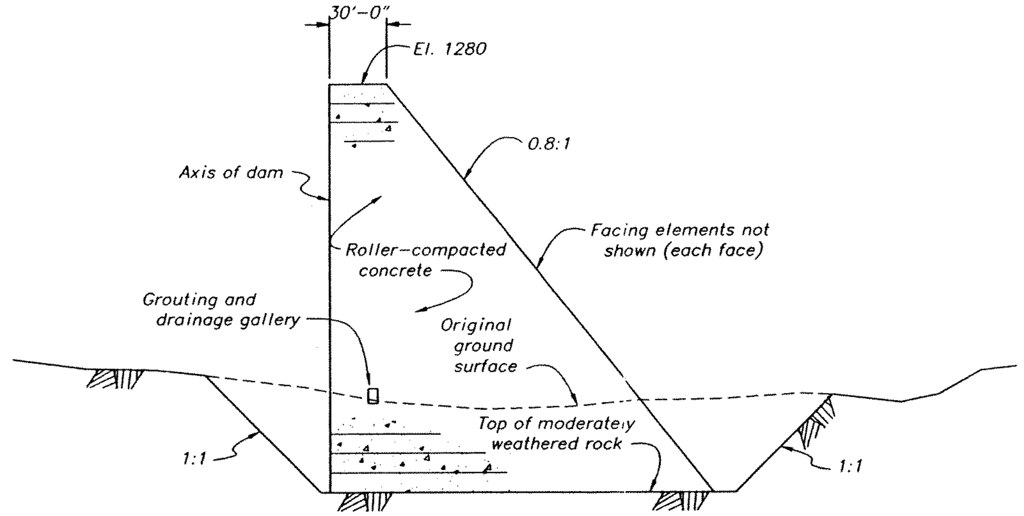
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT – CALIFORNIA

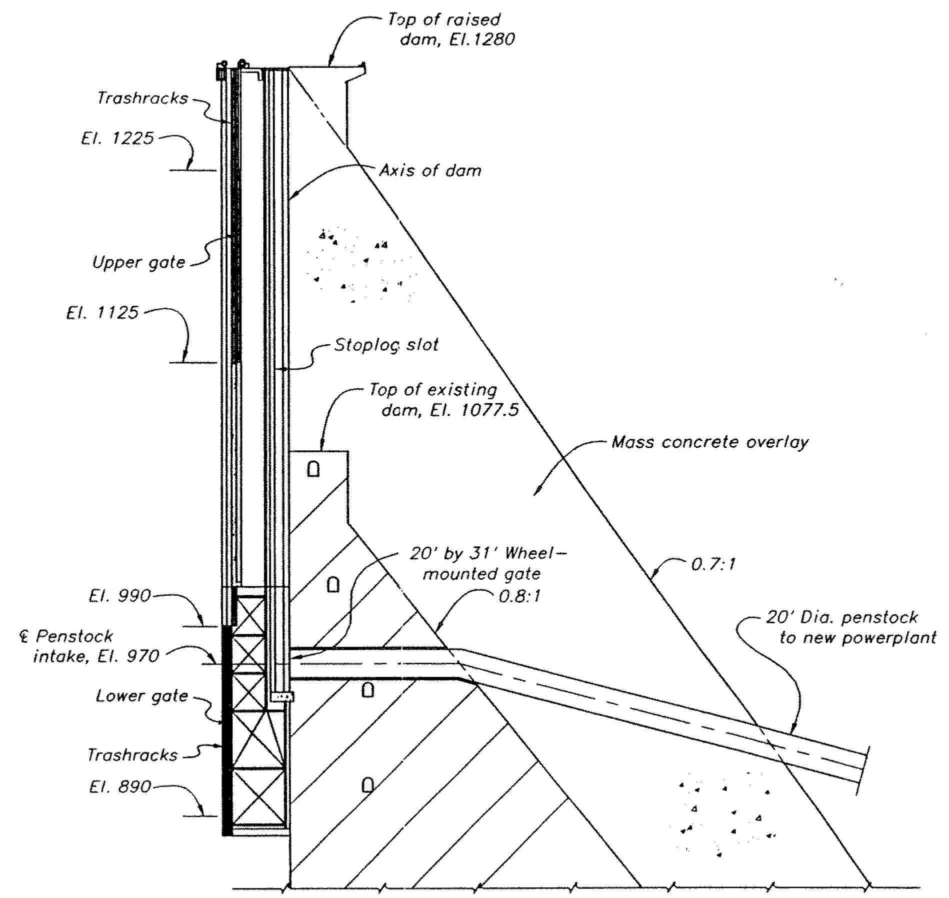
SHASTA DAM MODIFICATIONS
PLAN, PROFILES, AND SECTIONS – CREST EL. 1280
APPRAISAL DESIGN

DESIGNED T. HEPLER, F. JACKMAUH TECH. APPR. T. C. Hepler
DRAWN J. HARTMEISTER
CHECKED R. BENIK PEER REVIEW [signatures] WATERWAYS AND CONCRETE DAMS GROUP

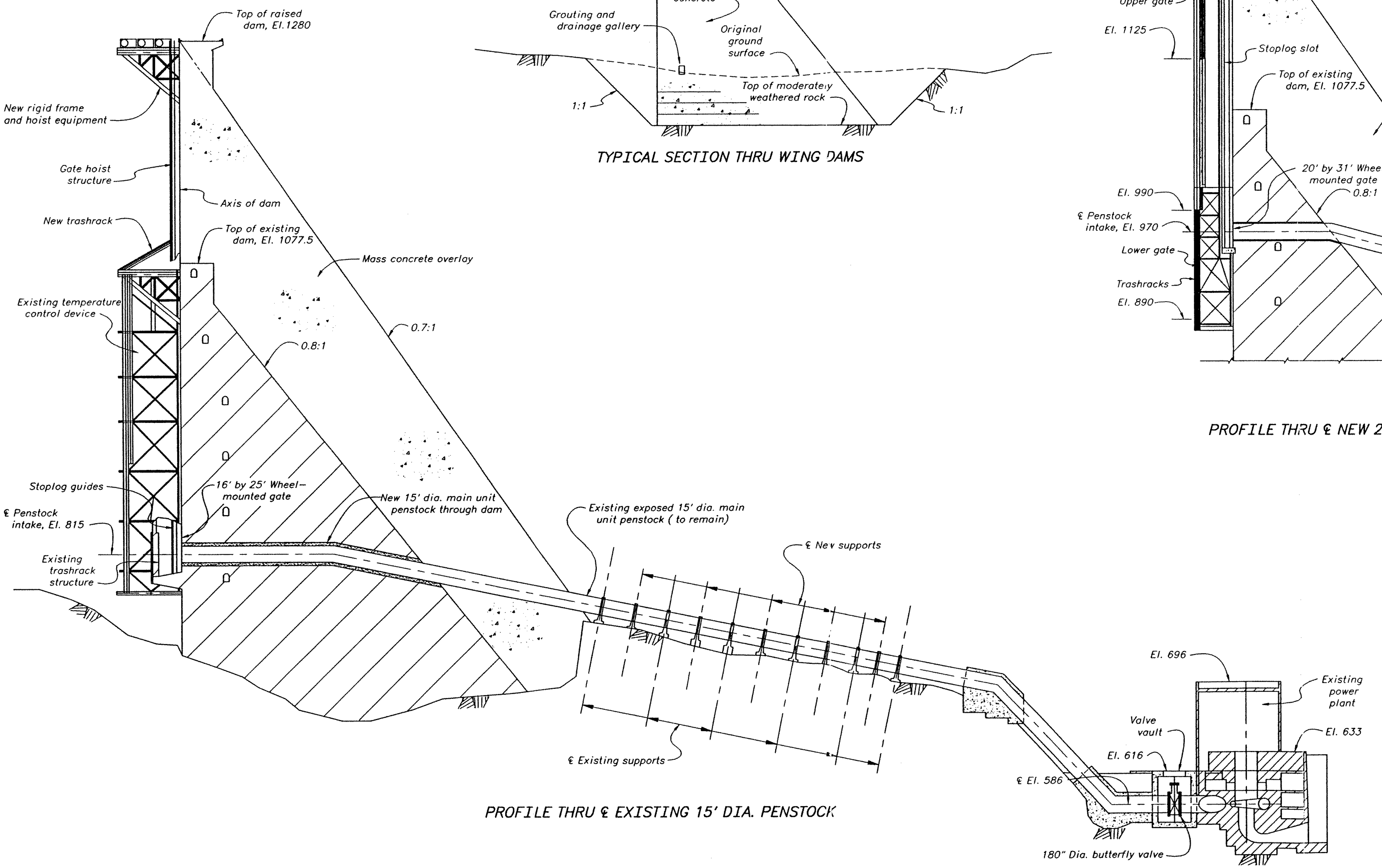
CADD SYSTEM AutoCAD Rel. 13 c4	CADD FILENAME 21423983.DWG	DATE AND TIME PLOTTED FEBRUARY 27, 1998 06:32
DENVER, COLORADO	FEBRUARY 17, 1998 SHEET 2 OF 3	214–D–23983



TYPICAL SECTION THRU WING DAMS



PROFILE THRU ℄ NEW 20' DIA. PENSTOCK



PROFILE THRU ℄ EXISTING 15' DIA. PENSTOCK

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT – CALIFORNIA

SHASTA DAM MODIFICATIONS

PLAN, PROFILES, AND SECTIONS–CREST EL. 1280
APPRAISAL DESIGN

DESIGNED T. HEPLER, R. LAFOND	TECH. APPR.	
DRAWN R. McWHIRT		
CHECKED R. BENIK	PEER REVIEW WATERWAYS AND CONCRETE DAMS GROUP	
CADD SYSTEM AutoCAD Rel. 13 c4	CADD FILENAME 21423984.DWG	DATE AND TIME PLOTTED FEBRUARY 27, 1998 06:37
DENVER, COLORADO	FEBRUARY 17, 1998 SHEET 3 OF 3	214-D-23984